SOCIO-ECOLOGICAL THEORIES AND EMPIRICAL RESEARCH. COMPARING SOCIAL-ECOLOGICAL SCHOOLS OF THOUGHTS IN ACTION

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INTRODUCTION: MULTIPLE DISCOURSES ON SOCIAL-ECOLOGICAL SYSTEMS

Environmental problems, at local scale as well as global scale, are now considered as key issues and scientists are encouraged to be part of the process to address these issues. For the last decades, scholars have been focusing on the study of interactions between social dynamics and ecological processes and produced a set of concepts and scientific discourses aiming at framing the analysis of socio-ecological dynamics and eventually at orienting interventions. Scientific discourses are produced by scholars who belong to different groups (resilience, vulnerability, political ecology, commons, robustness …) which identity go beyond disciplines, methods, frameworks and concepts and include a collective history on the evolution of ideas and research organization. Thus in this paper we will call these groups "schools of thought" instead of "approach". One problem in the field of social-ecological systems is the fact that these schools share concepts such as adaptation, vulnerability and others but this common vocabulary hides the differences of explanation schemes. For Gallopin "*the comparative analysis of the concepts of vulnerability, resilience, and adaptive capacity puts in evidence important similarities and differences, and in some cases contradictions, between the concepts as specified, or utilized, in different fields of inquiry. The comparison also shows that there is no generally accepted meaning for these concepts*"(Gallopín 2006). A set of papers aiming at examining the differences and similarities between alternative schools of thought were published. M. Janssen & E. Ostrom edited a special issue of Global Environmental Change on the relationship between resilience, vulnerability & adaptation (Janssen and Ostrom 2006; Vogel 2006) putting together different papers that present these concepts and two papers which compare them. In the first paper Gallopin concludes that resilience, vulnerability and adaptation are related in non trivial ways, because their epistemologies are different (Gallopín 2006) and in the second paper Vogel and co-authors (Vogel, Moser et al. 2006) consider that "*subtle differences in the understanding of concepts such as 'resilience', 'coping capacity', and 'adaptation' are frequently lost in the course of a growing multidisciplinary discourse*". They argue that the key point is the relationship between scientists, practioners and lay people. Depending on the type of partnership for knowledge exchange some doors for intervention will open or close.

Although some authors call for an integrated framework and some advocate for the diversity of explanations, both agree on the fact that there is a need for clarification for a better scientific debate and better interactions with the managers, stakeholders and interested people. The scientific debate remains obscure when it is based on abstract developments. This is why we have set a project aiming at understanding better several schools of thought, their differences and similarities, by confronting different scholars to the same concrete issues. This methodology is consistent with the research we have been conducting for the last twenty years (Bousquet, Barreteau et al. 1999; Etienne 2011): in a constructivist stance, we create arenas for the encounter of the different representations on a common object and we use mediating objects to favor the dialog. The role of the mediating object is to force each participant to link his discourse to a concrete object, making it understandable for other participants and eventually stimulating the group for the creation of a discourse articulating the different perspectives.

Different research units based in Montpellier (France) have been conducting research on socio-ecological systems (SES) to understand many types of relationships, including those between agriculture and biodiversity, policies and landscapes dynamics, watershed management, ecosystem management and health risk. A project named SETER (Socio-Ecological Theories and Empirical Research) was elaborated aiming at assessing the relevance and the complementarities of theoretical frameworks by applying and testing them on several empirical research case studies developed by the participating research units based in Montpellier. The purpose of this assessment was to clarify the respective potential of the different theoretical frameworks and to provide the basis for new conceptualizations of socio-ecological systems dynamics and management.

Each visiting scholar was asked to hold the flag of one school of thought on the interaction between society and nature coming from the disciplines of ecology, economics, geography, sociology & political science. Twelve senior researchers settled in Montpellier for short periods of time between 2009 and 2010. The same case studies were presented in the same way by the research units based in Montpellier to all invited researchers. Lance Gunderson and Allyson Quinlan (Resilience school), Marco Janssen (Common-pool resources and complexity school), Colin Polsky (global change vulnerability school), Nancy Peluso, Paul Robbins, Tor Benjaminsen and Tom Bassett (political ecology school) came from June to July 2009. A. Kinzig & C Perrings (Biodiversity & ecosystem services school), J. Anderies (Robustness and conservation of fragility school) came from June to July 2010. Lastly T. Lynam (Social representation & mental models school) spend September and October 2010 in Montpellier. Each of them presented the fundamentals of their school of thought during a public seminar, then they were grouped according to their school and they interacted with resource persons representing each case study, Denis Gautier & Martine Antona (Fuel-wood management in Mali), R. Mathevet (Managment of Camargue), J.-M. Vassal & M. Lecoq (Desert Locust Control) and O. Bonato (Phytosanitary risk management). On average each scholar worked for 15 hours with a given case study. They were requested to give a feed-back through an oral presentation presenting:

- The research question.
- The research process. How they would conduct the research?
- Data and information needed. Some data and information are already collected by the research teams; however, new questions may request additional data and information.
- Contribution to application field. What would the school bring to the case study in terms of additional knowledge, management recommendation, etc. ?
- Contribution to school of thought. How would this research contribute to the advancement of the research field?

This paper presents the material of this experiment, the interaction process and the lessons on the schools of thought and methodologies. Firstly, we introduce briefly the different schools based on the literature and on the presentations given by the invited scholars. Then we introduce the four case studies which were analyzed by the invited scholars and report on the interactions and their results. Then we present a discussion proposing a classification of the different perception of change which crosses the different schools.

THE DIFFERENT SCHOOLS OF THOUGHT

Considering the enormous amount of research dealing with SES, it was out of the scope of the SETER project to cover all schools of thought used by scientists. We have chosen some of those we consider to be the most visible and well-structured and also those which we considered to be complementary to those used by the research units based in Montpellier. Some researchers in Montpellier had developed research with different frames in mind and the wish was to create an arena for debate. We have chosen to invite scholars developing research in political ecology for the "focus on power" (between quotes the naïve common sense perceptions when the project started), vulnerability for the focus on "response to stress", resilience for the focus on "socio-ecosystems", biodiversity and ecosystem services for a particular focus on "ecological economics", robustness for the focus on "feedbacks and controls", commons and complexity for the focus on "institutions & rules", mental models and social representations for the focus on a "constructivist view". Before the project started we were thinking that these schools of thought are complementary (in the sense that it worth confronting them) because they take into account in different ways the social and the ecological component, the role of endogenous or exogenous change, the coordination through collective action or policies, etc. More than missing a given school the risk is here to hide the heterogeneity of points of views within a given approach.

A description of each approach and a discussion of the specific frames used by the invited scholars are in appendix 1. In brief:

- Political ecology. According to Paulson et al (Paulson, Gezon et al. 2003), political ecology was developed on a set of key ideas: 1) the idea that use of and access to resources are organized and mediated by social relationships that might impose a production rhythm that might be harmful to the environment (Watts 1983); 2) the recognition of different positions, perceptions, interests and rationalities in relation to the environment (Blaikie 1999); 3) the idea of connectivity across scales, which implies that local processes are influenced and influence global processes (Escobar 1999) the idea that social exclusion is the result of political economic and ecological processes mutually reinforced (Blaikie and Brookfield 1987). Based on the work of several scholars (Forsyth 2003) (Robbins 2004), (Blaikie 1999), (Zimmerer and Basset 2003), (Peet and Watts 1996) (Stott and Sullivan 2000), two main currents within PE can be distinguished. The first comprises empirical work on environmental activism related to struggles for resources and the formation of the state. This type of research provides a thorough analysis of environmental resistance of certain social groups (Bryant 2000) (Bryant and Bailey 1997). The second approach involves research about the construction of the environment as a discourse and the role of discourse and political action in the establishment of accepted definitions (Peet and Watts 1996) (Watts 1983) (Peluso and Watts 2001). This approach helps to understand the driving forces behind policy making. Some political ecologists give an important place to the biophysical facts and their relations with the sociopolitical conditions that accompany it (Turner 1999; Basset and Zoli 2000). Zimmerer and Bassett (Zimmerer and Basset 2003) proposed to work on socio-environmental interactions rather than on what they call "environmental politics" or "politicized environments".

- Vulnerability. Vulnerability has emerged in recent years as one of the central organizing concepts for research on global environmental change (Mccarthy and Canziani 2001; Turner II, Kasperson et al. 2003). Vulnerability is defined as the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation or stress, accounting for adaptive capacity. The vulnerability approach demands attention to human-environment interactions along three dimensions: exposure, sensitivity, and adaptive capacity. The frame for vulnerability assessment that was used during this project is composed of seven questions:
    1. Overarching Research Question: What explains the vulnerabilities of the [exposure unit] associated with the [hazard(s)]?
    2. Exposure unit: The [socio-ecological system] to be studied, delimited by [geography] and [time]
    3. Hazards: the one or more [stresses] threatening the socio-ecological system
    4. Units of analysis: the [objects] in the exposure unit to be sampled for study
    5. Exposure: description of the [intersection] of the hazard with the exposure unit
    6. Sensitivity: the [short-term impacts/responses] & [conditions] mediating the production of the impacts following the exposure
    7. Adaptive capacity: current/future [abilities & inabilities] to implement effective, long-term responses, determined in part by an understanding of previous impacts/responses
- Resilience. Following Carpenter et al.(Carpenter, Walker et al. 2001) social–ecological resilience is interpreted as (1) the amount of disturbance a system can absorb and still remain within the same state or domain of attraction, (2) the degree to which the system is capable of self-organization (versus lack of organization, or organization forced by external factors), and (3) the degree to which the system can build and increase the capacity for learning and adaptation. There is an increased emphasis on the notion of transformability ("the size of a stability domain or the amount of disturbance a system could take before it shifted into alternative configuration") into improved social–ecological systems as opposed to adaptation to the current situation ("ability of systems to absorb changes of state variables, driving variables and parameters, and still persist"). An emphasis on transformability implies extending the focus in social–ecological research to systems of adaptive governance (Dietz, Ostrom et al. 2003) in order to explore the broader social dimension that enables adaptive ecosystem-based management.
- Commons and complexity. The general frame is the dilemma between individual and group interests. The group interest would be to cooperate while individuals' interest is to free ride on effort of others. Institutional arrangements provide incentives to stimulate individuals to contribute to the common good, monitor outcomes and enforce rule breaking. A set of papers in a recent issue of PNAS (Ostrom, Janssen et al. 2007) focused on the problem of fit between ecological dynamics and institutional arrangements. The question is: how do appropriators craft

institutions and what helps them to fit it to the social-ecological context? The analysis of case studies follows a diagnostic approach where initially broad themes of social and ecological components of the social-ecological system are investigated before digging deeper into the specific attributes of the system. The complexity of the system is caused by the complex interdependencies of the attributes of the system at different scale. Although each case is unique, one can formulate stylized findings that can be replicated in controlled experiments, such as the importance of communication, trust and ability to contribute to the crafting of rules (Poteete, Janssen et al. 2010)(Poteete et al. 2010).

- Robustness and conservation of fragility. The field of robust control (Zhou and Doyle 1998) has been developing management tools for highly uncertain systems and ideas from robust control have made their way into economics, engineering and management science. The influencing authors behind the robustness theory are T. Schelling (Schelling 1978), D. North (North 1990), M. Olson (Olsson 1965), O. Williamson (Williamson 1996). The main objective of this analysis is to (i) determine whether it is possible to develop practical management strategies with general robustness to parameter variations that yield reasonable performance, (ii) shed light upon underlying fundamental robustness-performance-vulnerability trade-offs, and (iii) provide some social, institutional, and economic intuition for the results. In order to connect the case studies and formal models, the framework developed by (Anderies, Janssen et al. 2004) (Figure 1(A)) which highlights relationships between groups of actors and biophysical context is used. Figure 1(B) shows a specific instance of a general SES shown in (A) for an irrigation system.
- Biodiversity & ecosystems services. The biodiversity and ecosystem services approach contributes to the "problem-driven"sustainability science, which aims to "change the way science of human use and impacts on environment is being done" (Perrings 2007). Two of the key issues for sustainability science are uncertainty (on the structure of the socio ecological system and the measure of its performance) and learning in the decision process. The BD&ES approach questions the assertion of positive linkages between biodiversity and the various ES, by focusing on necessary trade-offs to obtain both conservation of biodiversity, flows of ES and human development, and on the decision problem. The ecosystem services framework has four main consequences for target setting (Perrings, Naeem et al. 2010):
    1. "what and how much biodiversity should be targeted for conservation depends on what services are important to maintain and with what reliability;
    2. the temporal and spatial scale of targets should be based on the changing temporal and spatial distribution, and risk profiles, of ecosystem services;
    3. target development and implementation should include all agencies involved with management of biodiversity and the ecosystem services they support;
    4. interdependence among ecosystem services, the benefits they provide, and the value placed on those benefits implies that targets must be conditional".
- Social representations and mental models. Modern theories of social change (Giddens 1984; Archer 1995) note the dualism between social structure and agency; social structure constraints

or enables the actions of social actors and people modify social structure through their actions (agency). As important components of social structure, social representations and mental models constrain or enable human action and are modified by human action. Social representations are the common sense and hence socially shared representations of the world that have core (fundamental and slowly changing) and peripheral (more individual and changeable) elements. For the purpose of this exploration of SETER project cases mental models are taken to be the representations that individuals construct of the world about them at a given time, in a given setting for a given purpose. A number of elements of a group's representation of a situation will be used to focus the analysis of SETER project cases. Firstly how a group and how different groups name or label a situation is important; whether it is labeled as a problem or as an opportunity, or as a crisis or a concern the name or label provides an indication of the group's conception of and valence towards the situation. Secondly, how the different social groups that are represented in the mental models of a specific (reference) group as well as the naming or labeling of these groups may provide information on the reference group's construal of the actors in the situation as well as the reference group's relationships (including valence) to these actors. Thirdly, the referent group's naming or labeling of factors contributing to the situation or their naming of courses of action that they promote will tell us about the referent group's mental models of causality or action.

CASE STUDIES

Two case studies (Camargue & Mali) were investigated by researchers familiar with integrative approaches to socio-ecological systems. The two other case studies come from research teams who have been involved in the management of risk associated with the ecology of insects and who recently opened their windows of investigation to better understand the social drivers of these processes.

WETLANDS OF THE RHONE RIVER DELTA (CAMARGUE, SOUTHERN FRANCE)

The Camargue Biosphere Reserve lies in the Rhone river delta bordering the Mediterranean coast in south-eastern France. This deltaic system covers an area of about 145 000 ha and is characterized by a mosaic of fresh, brackish and saline wetlands interspersed with areas used by intensive agriculture or industries (Mathevet 2004). It is recognized as a wetland of international importance for the diversity of its ecosystems and the large numbers of breeding and wintering water birds (Heath and Evans 2000). Covering about 16% of the whole Camargue area, rice is the most widespread crop in the delta, either in rotation with wheat or in monoculture; the alternative crops being limited by soil salinity (Barbier and Mouret 1992). Earlier studies have highlighted the strong complementary roles of farmland and natural habitats for water birds (Pirot, Chessel et al. 1984; Hafner, Dugan et al. 1986). During the last 20 years, the management of these wetlands has been characterized by the building of embankments, the mechanical removal of vegetation, freshwater pumping, and control of water levels; all leading to a loss of biological diversity (Tamisier and Grillas 1994; Mathevet R. 2007). There is a need to reconcile wetland conservation with the development of an economic activity (wildfowling) whose financial contribution to local agriculture allows essential natural water bird habitats to be preserved. Moreover, while facing the global change and increased involvement of local stakeholders in regional planning, the

managers of the Camargue Biosphere Reserve need to develop adaptive co-management strategies and methods to adjust land use and conservation policies to climate change, agricultural policy evolution, industrialization, urbanization, tourism development, and Rhone river flooding and sea level rising. For many years researchers have been examining how the local landscape has changed, and how changes in land use and water management practices have affected the population dynamics of bird species and conservation status of wetlands.

LOCUST CONTROL IN THE SAHELIAN REGION

Since the distant past, for many of the poorest countries of Africa, desert locust has been one of the most serious crop pest (Steedman 1990). People living in these countries have been seriously hampered by damage caused by this insect. The basic scientific locust control principles were first outlined by Boris Uvarov (Uvarov 1938). To mitigate the risk of crop losses, the requirements are a good understanding of the species' ecology in order to be able to locate outbreak source areas and carry out preventive control, and also an excellent international cooperation, which is essential due to the high migration potential of this locust. Research efforts undertaken for a long time resulted in the setup of a preventive control strategy (FAO 1972; Hafraoui and McCulloch 1993). Preventive control organizations were created in various countries. The control strategy implies monitoring ecological conditions and the locust in its outbreak areas, and conducting preventive treatments against the first gregarious locusts. Regularly applied and improved, this strategy made it possible to reduce the frequency and the duration of the invasions since the 1960s (Skaf, Popov et al. 1990 ; Lecoq 2001).

However, these invasions persist. The latest plague indicates that it is now essential to radically change our way of thinking, perceiving and dealing with this problem, and to introduce new and innovative approaches to locust issues. The recent plagues were the result of major malfunctions in the desert locust preventive control strategy, and it is clear that current problems in the management of this natural risk are mainly organizational. For this, we need to consider the locust problem not solely in terms of crop protection, but as a natural hazard with many impacts: agricultural, economic, social, environmental, and political. The rationales and strategies of diverse stakeholders can be convergent or divergent, and enhance or hamper efficient locust control. A lack of recognition and understanding concerning the many different stakeholders involved in desert locust management - and their operational rationales - is a critical shortcoming.

Nowadays, desert locust problems should clearly be seen as a risk management system for a natural disaster, still considering standard biological and ecological mechanisms as in the past, while also integrating studies on social, economic, organizational, and cultural mechanisms that were generally overlooked in the past.

MULTIPLE USES OF SAHELIAN ECOSYSTEMS AND RESILIENCE OF INSTITUTIONAL ARRANGEMENTS

Sahelian ecosystems are known for their intricate multiple uses of their resources: fuelwood (supplying 90% of the energy needs of urban and rural populations), farm and extensive grazing land, non-timber forest products for human and livestock consumption, habitat for biodiversity, carbon storage, etc. These ecosystems have been often described as man-made systems threatened by the exploitation of a

rare and disperse forest resource, and by land encroachment through the conversion of forest into arable land (Fairhead and Leach, 1998). But Sahelian ecosystems demonstrated their resilience following the severe droughts of the 70s. The continuous co-evolution of the biological (trees & grasslands) and social components played a major role in buffering the effects of environmental variability (species adaptation to fire, weed dispersal by livestock, etc.).

A Malian case study is selected to illustrate the trends affecting the social-ecosystems of the Sahelian region of Africa. But in all the Sahelian countries, the post-drought period has seen the emergence of new institutional arrangements to reintroduce territorial organizations and controls on resource use through devolution policies (Agrawal and Gibson 1999; Gautier, Hautdidier et al. 2008).These socio-ecological systems need to cope with numerous constraints: limited productivity of natural ecosystems, increased urbanization leading to stronger relationships between urban needs and rural development, extensive agriculture with low physical productivity level, pressure on land availability, environmental variability, and limited rainfall.

In extensive farming areas, the enforced fuelwood management policies illustrate the tension between the demand for energy of urban populations and institutional arrangements fostering the local management of the resource (Benjaminsen 1993). The Cirad was involved in research supporting the implementation of new forest policies based on a more important involvement of local people in the resource management. Field works were conducted and data were collected on ecological productivity, on and implementation monitoring. Then research looked at the issue of land conversion to extensive agricultural production and the enhancement of agricultural production. Nowadays, a new paradigm is required to ensure a balance between biodiversity conservation and agricultural production, and to cope at the same time with poverty alleviation.

MANAGEMENT OF BEMISIA-PHYTOVIRUS RISK IN PROTECTED CROP IN MEDITERRANEAN ZONE.

In France, tomatoes produced for the fresh market are mainly grown in heated greenhouses with long cycle of continuous crop (11 months). Before the year 2002 , 80 % of growers were controlling tomato pests using Integrated Pest Management based on biological control (IPM –BC), a strategy that uses fewer insecticides, because the durability of their production depends on quality. In 2002-2003, growers were the powerless witnesses of a new phenomenon which devastated their crops. The culprit *Bemisia tabaci*, a small insect is considered to be a major pest on a worldwide scale.

The sudden outbreaks of *B. tabaci* populations in greenhouse tomato productions in south of France in 2002-2003, associated with the *TYLC* the insect was carrying, generated a major phytosanitary crisis. The presence on tomato of *Bemisia* infested by *TYLC* increased considerably the harmfullness of this whitefly, questioning progress accomplished these last twenty years in IPM-BC. The impact of the *Bemisia-TYLCV* was so strong that it destabilized the whole commodity chain of greenhouse tomato production in the two main production basins (Languedoc-Roussillon and Provence Alpes-Côte d'Azur regions). Thus, the first reaction of French authorities was to classify the virus as agent of quarantine and to supplement European directive on the spread of viruses by orders of obligatory control of *TYLC*. In concrete terms, the presence of *TYLC* has to be declared to the Plant Protection Agency services (SRPV) and the whole crop has to be pulled up without financial compensation.

In a context of internationalization of markets, the organoleptic qualities as well as sanitary status of fruits and vegetables, the environmental quality of crops, and the marking of fresh products, are nowadays considered as corner stone for developing such agricultural activities. This postulate is based on the considerations made by the professionals and pressure by customers around the theme "fresh product = health factor". At European level, policies are going the same way restricting very strongly the use of chemicals. Because of progress during the last 20 years in terms of Biological and Integrated Protection, especially on tomato crop, this objective seemed reachable (Van Lanteren 2000). But the introduction of whiteflies infested with viruses has "de facto" generated a phytosanitary crisis questioning all the knowledge by considerably lower the damage thresholds (Fargues, Bonato et al. 2004).

RESULTS: THE SCHOOLS OF THOUGHT AND THE CASE STUDIES

After their interactions with the scholars holding the case studies, invited scholars presented the results of their investigations. These presentations are included in appendix 3 that was written by Montpellier's researchers, and checked by the scholars who interacted with them, formulated new research proposals and formalized them in a presentation. From this material we propose the following synthesis for each school of thought. The synthesis is divided in three parts: what is the scientific framework used to formulate new paths of research for the four case studies? What are the selected methods to conduct the proposed research? What would be the contribution of such research to the understanding of the SES of the four case studies dynamics and conversely the contribution of the case study to more theoretical debates? Table 1 presents a synthesis.

RESILIENCE AND THE CASE STUDIES

Scientific framework:

The resilience point of view has its roots in system analysis perspective. The socio-ecological system is described as having alternative regimes or system configurations (Table 2). The theoretical framework of resilience focuses attention on the system's key variables, by scale and sector and how these variables interact to influence shifts between regimes.

For instance in the Sahelian case study, Gautier and colleagues (2005) described how tree density, biomass and diversity at the landscape scale, vary with land use and can create different ecosystem states. One state is the savanna state, another the agroforestry parklands, and another is a fallow state. Each of these alternate states can transition into the other and each provides different bundles of ecosystem services. This case study involves a change in the social regime of how forest resources are used and managed. However, there is no evidence that the change in policy led to a different ecological state. Although the policy regime changed, including the rules and some connections between actors, there has been no discernable ecological shift to an alternate state within the time scale considered. The whitefly (*Bemisia*) threat to hothouse tomato production in Southern France highlights the role of cross-scale dynamics, as described by panarchy theory (Gunderson and Holling 2002). The Bemisia case reveals panarchies or cross-scale interactions that occur at different phases as the system shifts from one of low TYLC virus levels to a high outbreak level, which is considered an alternate regime or state. In

particular scholars look to see how the key factors interact across levels from plants to greenhouse, region, and nation. Top-down interactions include crop compensation, control policy, and technology/energy inputs. Bottom up interactions include ecological TYLC outbreak dynamics and tomato production practices.

The issue of learning is also raised: what do the actors of the system learn? Does the system learn? In the case of locust management, a resilience approach might address the links between traditional knowledge and modern monitoring and address the functional role of locusts in an ecological system (e.g., nutrient recycling).

Methodology

Different methods were proposed to investigate on the four case studies.

- Historical analysis. The objective is to understand the systems shifts in the past and also to understand the role of slow variables. For instance is the following story of the Camargue SES (see appendix 1).
- Comparison with similar problems. For instance to progress on the desert locust management it is proposed to undertake a comparative institutional assessment between international centers for disease control and US interagency fire fighting.
- Institutional analysis. Again on the desert locust management it is proposed to conduct an institutional analysis and to propose alternative institutional settings.
- Modelling. Modelling is proposed for every case study. These would be developed as tools to integrate understanding of complex dynamics and to inform possible new interventions. For Bemisia, case development of food base, predator and regional scale spread models in addition to biophysically based population models.
- Scenario analysis. Also, some of the cases might benefit from the use of scenarios as advocated by Carpenter (Carpenter, Bennett et al. 2006).

Contribution

Two types of contributions can be defined: contributions to the problem at stake and contributions to generic questions. As for the contribution to generic questions most of the outcomes lie in lessons from questions such as:

- Managing for specific vs. general resilience (i.e., specific resilience of the tomato production system to TYLC vs. the general resilience of current greenhouse food production practices to future pest outbreaks and other unforeseen events).
- What can be learned from the case study about tradeoffs in managing systems at the edge of stability domains? Does compensation subsidize pathology or force adaptation? Intensive agricultural systems are presented as being the result of a trade-off between efficiency and resilience. The hypothesis is that intensive agricultural systems target the efficiency and pay the price in terms of resilience. As an archetypical example, the Bemisia case study would contribute to this theoretical question.

- What is the cultural landscape resilience, and more precisely the relationship between land use heterogeneity (mosaic and patchy landscape) and resilience? As an example, for the Camargue case study the focus is on both (i) its dependence on how local communities and stakeholders managed flips at smaller scales (reed harvest/duck hunting, rice / wheat cropping) and (ii) its dependence on reversibility of regimes. Water levels trigger the flips between states; water regime management at smaller scales reinforces landscape level heterogeneity of land cover and human activities.

COMMONS & COMPLEXITY AND THE CASE STUDIES

Scientific framework:

This lens combines a complexity approach with the theoretical framework of E. Ostrom on institutions, individuals and management of the commons. Approaching the four case studies with this point of view reveals that problems are all conceptualized as a problem of adaptation and analyzed through the incentive structure of the SES for different stakeholders. For instance the desert locust management is analyzed at different scales. The problem is framed as a public good provision problem at international scale with important asymmetries of costs and benefits. There are rules on paper and rules in use. Institutions also adapt and change. For instance, in the case of desert locust management, there is the problem of loss of institutional memory. These questions of incentive structure have to be taken in their dynamic context: the environment changes. Thus research has to be done on ecological and bio-physical dynamics.

Methodology

The recent book of Poteete, Janssen, Ostrom (Poteete, Janssen et al. 2010) have advocated that many methods should be used in combination. However from this screening of the four case studies we see that there are some favored methods.

- Survey analysis on the incentives and experiments to test the incentive structure. In Bemisia case experiments could be done: given insights in attributes of producers, what are incentive structures to lead them practice preventive actions? In the Sahelian case, experiments with and without strict enforcement could be done. The problem of strict enforcement by bureaucrats from city is an economic game. Experiments could be done on decision dilemmas to see how people perceive harvesting problem.
- Modeling to integrate the different types of knowledge. For the locust, it would be a spatial explicit model with locust bands, rainfall events, and different levels of local control. Countries would be “human agents” controlling desert locust. The question would be: what would be long term evolving strategies of agents to different types of institutional arrangements and ecological dynamics? Modelling can be used also to explore the ecological dynamics: the proposed method is to study spatial ecology of Bemisia building spatial explicit simulation model at farm level to access (spatial) policies and diffusion of virus among farms. This would define a model structure for future outbreaks.
- Remote sensing and field work for scientific evidence on land use and land cover changes.

- Scenario analysis can be used (what are the important problems for their children, visions, solutions). The goal of the analysis is to engage the creativity of the local stakeholders in visions for future and possible solutions. For instance in the Sahelian case study it would be interesting to bring together stakeholders and do scenarios exercise: what are alternative energy sources: oil exploitation? What if carbon sequestration market will play a role?
- In terms of research on management, one could use role games to train decision makers at local and national level.

Contribution

The four case studies contribute to answer the question of the decision making of individuals under different incentive structures: how are different actors able to adapt through their decisions? This leads to investigations on the one hand on the risk attitudes of the actors and the trust they have in the system and on the other hand on the policy impact and adaptations of the actors. A generic question is on who benefits and who loses (ex in the locust case Locust research, National governments and control centers, Pest control industry).

Bemisia is an instance of a generic problem: the producers are able to move from one high gain high risk production system to another, especially by harvesting subsidies. The hypothesis is that the farmers are highly risk seeking, low trust in other producers and "government". The agricultural systems have evolved to go through overshoot and collapse cycles. The question is: what institutional incentives lead to this type of 'agents'? The hypothesis is that long-term focus on subsidy (money and research) leads to certain type of producers who are well adapted to institutional arrangements, but food production system is less reliable.

POLITICAL ECOLOGY AND THE CASE STUDIES

Scientific framework

Four different scholars participated, each of them having a particular framework in mind. However through the four case studies, a set of frames can be identified, focusing on:

- A history of social and political relationships linked to the topic. Can we learn from the past to cope in the present? How did present dysfunctions come to be and how might they be undone? For instance for the desert locust management the problematization should be situated in colonial history and transformation of governance in the modern era. Theoretically this work is framed by the idea that colonialism and capitalism transformed the "crisis" owing to the larger political economy.
- An analysis of the accumulation and dissipation processes. The risk regime persists because there is accumulation somewhere in the system. Where are the interests and how are they interested? The risk regime is locked into place by interests that benefit from, and are rewarded by, the current pattern of accumulation and management. For instance, for the Bemisia case study, the value accumulates along the current commodity chain. The risk regime persists because there is accumulation somewhere in the system. For locust management, while locusts go through a cycle of outbreak and invasion, and the

international community goes through a cycle of motivation and oblivion, the donor and receiver countries and institutions go through a cycle of "resource generation" and "dissipation".

- An analysis of the interactions between different knowledge sources. In the locust control case theoretically, the problem is a problem of confrontation between local ecological knowledge (*metis*) and state knowledge (*techne*). The goal of the study according to this theme would be to understand local actors, perspectives and narratives working along Scott et al. (Scott 1976) line on proximity of experience of local people and its conditioning and assembling network of knowledge amongst diverse public. The knowledge and the memory is also the knowledge of the institutions. The theoretical framing lies in Douglas work (Douglas 1986): institutions do the remembering and the forgetting.
- An analysis of political processes for the control of actors and territories. For instance in the Sahelian case the thesis is that various actors use the territorial and institutional dimensions of the wood fuel project to expand their control over people and resources in competition with the State. According to a Political Ecology lens, Malian forestry project may be seen as representing an effort of international development interests to domesticate the Malian state and its forestry sector, make it congruent with rational forestry practice, and future economic development interests. In order to transform Malian natural resource management, the project fosters new identities for state actors and citizens, all associated with a specific territorial and property logic, and tied to specific market skills. In the desert locust control case the problem lies in the spatial/territorial mismatch of political territories and locust breeding sites (micro) and invasion paths (international). What geopolitical and agro-economic conditions prefigure cooperation or cooperative failure?

Methodology

There are many methods. For the four case studies different methods were suggested:

- To follow the money (Klinenberg 2002) with a careful accounting of when funds flowed, what was bought, and where did the materiel go. This is the case for the desert locust management and for Bemisia case.
- A historical re-evaluation of relationships among actors. In the Sahelian case it would be done for relationships among woodcutters, chiefs, other "old" and "new" authorities, funders, and other actors.
- Ethnological approach. For instance in Sahelian case study, the approach would be an ethnography of state actors.

Contribution

As presented in the "scientific questions" section, the four case studies give instances of concrete debates. For instance:

- Globalization exacerbating international problems: trans-boundary problems cannot be solved by trans-boundary organizations. This general issue is here linked to the ecological process: what type of dispersed governance should be organized for dispersed ecologies?
- How states respond and evolve when facing new ecological challenges (all cases)?
- The role of capital accumulation. Where does development capital accumulate?
- The articulations between public resources (for instance in Camargue water in its various forms) and private uses (for instance land uses in Camargue).

VULNERABILITY & THE CASE STUDIES

Scientific question

The main hypothesis of this approach is that vulnerability demands attention to human-environment interactions along three dimensions: exposure, sensitivity, and adaptive capacity. The assumption is that there is an object which is vulnerable to a hazard. The identification of the object and the hazard are the first steps. There is a before and an after the exposure. The "after" is studied at two different time scales, the short term and the long-term. The vulnerability analysis is related to a concept of reaction to cope at short term (sensitivity) or long term (adaptive capacity) with hazards, which suppose control for responses, liability to provide responses and potential reorganization of the system.

Methodology

The vulnerability approach does not suppose a particular methodological approach. The result is therefore likely to be a disparate collection of methods that are usually not viewed together in the same project.

From the four case studies we extract the following methods:

- Interviews and surveys. One could imagine answering the research question "In what ways are L-R tomato production practices influenced by French consumer preferences?" through a combination of an inventory of production practices by on-site observations with interviews of producers about how the importance of consumer preferences. The result would be two measures – one of producer attitudes, and another of producer behavior – that could be correlated in a statistical framework.
- Analysis of archives. The analysis of the exposure needs to characterize the situation before the exposure. For instance for the locust control: how was the vegetation managed before the swarm? Were the herder groups, prior to the swarm high/low social status? numerous/small? old/young? What was the socio-political stability of the country prior to the swarm?
- Biological experiments. For instance to answer the sensitivity research question "What is variation of Bemisia related to variation of temperature in the field?" one can imagine a study that combines biology-based sampling methods for counting flies in a greenhouse with temperature measurements, spread over multiple times of day, multiple days, and multiple

greenhouses, with the results being combined into an index appropriately weighted, for example, by size of greenhouse, greenhouse location, etc.

Contribution

The contribution of this approach is obvious for the management. Vulnerability analysis helps identifying the exposure and the favoring the responses to exposure.

The cases study may contribute to generic question: How should the information gathered from the research be combined across the three dimensions *(*exposure, sensitivity, and adaptive capacity)*?* This question marks one of the frontiers of vulnerability research. This frontier is not only a matter of how to combine information of multiple types; social science offers many examples of how to do that. Instead, this frontier is mostly a matter of how to combine information both within and across the three vulnerability dimensions.

ROBUSTNESS AND THE CASE STUDIES

Scientific framework.

A framework is proposed which describes the interactions between the four main entities of the system (resource, resource users, public infrastructure, and public infrastructure providers) (Figure 1).

The challenge is to link details of the cases to the structure of the cases. Every case has a structure. Within the above frame, the analysis has to describe the micro level incentives, the micro-structure of the biophysical context and the feedbacks and information flows at system level. Three frames can be used. The two first frames represent the agents and the rules (figure 2). Agents have capacities (divided in action on biophysical component or information processing capacities) and goals (divided in material or meaning). As an illustration figure 2 represents the locust case. In red is shown the fact that the focus of this study is on the ability of the agents to process information. The system is also made of rules, either biophysical or contractual among the agents. Humans make contracts, ie they acknowledge the rules and the rights of the others. Then there is the dynamics of the system (figure 3): a resource is controlled, and there is a sensor on this control which leads to a feedback on the resource and the control.

Method

There is no preferred method. Any method which allows the identification of the actors and their relations is usable. As for the dynamics, models are proposed to analyze the dynamics of the system and the potential role of controls.

Contribution

Once described with the framework, most of the analysis lies in the understanding of the feedbacks process, and how the system is driven by these feedbacks. In Bemisia case for instance we had seen that the feedback cut, ie no more information flows to the pest control system, leads to an increased fragility of the system. It is also interesting to see how a system will organize itself to generate values (in other word possible accumulation). An example is Camargue: through water control the objective is to produce and extract values.

BIODIVERSITY & ECOSYSTEM SERVICES AND THE CASE STUDIES

Scientific framework.

The general frame is based on interactions within SES, linking changes in ecosystem structure and functioning to changes in ES delivered to society, and assessing the human responses to these changes in ES. The core of the approach is the identification of ES flows and their changes due to perturbation. That perturbation can be an ecological stress, changes in actors' behavior or an intervention (such as policy). It involved considering the scale (scale of management and scale of the effects) and the inclusion of a range of ES impacted in different ways that can affect the potential human responses. In the Mali case, an overarching question was identified: What and how a particular perturbation (ie the fuelwood policy) with widespread socio-economic and ecological consequences impacts ES flow?

Method

This approach builds on:

- Survey and baselines are used to identify long term trends; one of the issue of this approach is to define the area of study, which will be further refined when determining the Foot Print Area (FPA). This FPA is potentially larger than the area directly covered by the perturbation at study. In the Mali Case, since the approach requires the evaluation of a perturbation, it is necessary to establish baseline conditions/trends against which to track its effects. The baseline should fix status and trends at the introduction of the perturbation: the demographic, socio-economic and biogeophysical landscape of the study area, the array of ecosystem services sourced from the FPA, the institutional conditions within which ecosystem services are generated and distributed, the final demand (goods and services that people value) that are supported by those ecosystem services. The BD&ES approach needs to collect spatially explicit data that should based on a sufficiently long time series that we can have some confidence in the projections. Data on the biogeophysical characteristics of the landscape should be spatially explicit, making it possible to map the landscape changes due to the policies. Data on socio-economic, institutional and other conditions may be either spatially explicit or spatially non-explicit.
- Identification and measure of changes in ES flows (spatial changes, temporal changes, increase of variability) and set of beneficiaries: once the series of perturbation are identified, the approach studies their impact over the supply of ES (provisioning, regulating, cultural) and the value of natural capital by answering the following:
    - What are the most important ecosystem services?
    - How have the physical flows of these important ecosystem services changed?
    - What is the spatial reach and variability of each ecosystem service, and how has the spatial reach and variability changed?
    - How has the temporal variability in the delivery of each service changed?
    - How resilient are the flows (are there thresholds in the system)?
- Evaluation and modelling (spatial or not), to measure the consequences of the perturbations for the value of the natural capital asset and any other asset, and to identify governance

mechanisms –institutions and incentive structure- that have the potential to induce sustainable provisioning of ES across scale. The main consequences. Unsustainability is defined as a decrease in assets value. The BD&ES approach defines sustainability as being non-declining inclusive wealth (natural capital, human capital, social capital, built capital, financial capital).

Contribution

A generic research question is: "If the full array of (spatially and temporally distributed) ecosystem services delivered by specific landscapes, and the full set of (spatially and temporally distributed) beneficiaries of those services are taken into account, how should this affect landscape management over the expected range of conditions?"

This approach gave insights on concrete debate in the human-environment sciences. How to tune local institutions and social infrastructure and policies to value generating schemes avoiding the alteration of ES (Bemisia, Mali) or disservices? Why valuing ES, at different scales and the notion of off-site ES (Mali, Camargue, Locust)? Is perturbations part of systems and generating adaptive responses or not (Locusts outbreak, Camargue).

SOCIAL REPRESENTATIONS & MENTAL MODELS AND THE CASE STUDIES

Scientific framework.

Social representations are systems of values, ideas and practices that are co-constructed by individuals. They are a collective construction which enables people to orient themselves, to achieve mastery over social and physical world. Most of it is in the words of Moscovici (Moscovici 2000): it is common-sense. Mental model is a cognitive representation of a phenomena held by an individual. It draws on social representations, personal beliefs and experiences and ancillary information. People do not carry around compiled mental models. They compile it in a given context, at a given moment, in a particular setting. Settings are the social field in which social action happens. All SETER cases are in the complex domain. One cannot expect prediction, causal relationship. The role of science is to probe, to try, to do action. The objective is to define intelligent probes and to make sense of what happens from those probes.

Method

Methods are about settings (are we in an outbreak or remission phase? In the site of far from the site?), time and groups (which groups?). Mainly the methods would do documents analysis, media analysis and word association. From this analysis the thematic areas are identified. Then a setting (a story) is created and people are asked to react in this setting (for instance you are with people and you have to explain what's going on with the locust). You ask people to write a story, this would be the narrative. Then the texts are analyzed with software and the correspondences with the different themes are established.

Contribution

For the case studies this approach facilitates the acknowledgment that there are different perspectives, different points of views of the problem at stake. It helps acknowledging what are the representations which maintain the system and how much they are related to hidden perceptions, to know the perception of the other groups, to trace the sources of narratives and see the relationship between the

narratives and action. The contribution to more generic issues is the contribution to the relationships between settings and representation and action. If people are placed in such or such setting they create different mental models which lead to different actions. The last contribution is a contribution to action. The role of the scientist is to reveal and name the social representations and the observed patterns related to this plurality or consensual representations. For instance in the case of Bemisia and locust the analysis of this set of representations shows that their interactions maintain the system in a given state.

DISCUSSION: DIFFERENT MODELS OF CHANGE ACROSS SCHOOLS

The objective of the SETER project is to understand better the different schools of thought based on their confrontation to the same case studies. Looking across the different lessons of each school investigation on the same set of case studies, similarities and complementarities emerge. Many discussions are possible from the material accumulated in SETER project. After a literature review on the comparisons among schools, we propose a discussion which presents a cross-school synthesis on the different models of change.

LITERATURE REVIEW

In the scientific literature schools of thought are often compared by pairs or triads.

- Resilience and vulnerability are often considered in opposition, although deeper analysis indicate that the relationship between these two concepts is more complex and they can be used in combination (Sallu, Twyman et al. 2010). Cifadoz (Cifdaloz, Regmi et al. 2010) assemble robustness and vulnerability in a trade-off relationship. Turner II examines vulnerability and resilience through their contribution to sustainability and concludes that "*At their most fundamental level, vulnerability and resilience constitute different but complementary framings. The former seeks to identify the weakest parts (those most affected negatively) of coupled systems to disturbances, and the latter, the systemic characteristics that make systems more robust to disturbances*" (Turner II 2010). Miller et al. (Miller, Osbahr et al. 2010) state that the resilience community tends to prefer a systemic approach, whereas the climate change adaptation and the vulnerability communities tend to take an actor-oriented approach. Hence, resilience has advanced the understanding of system dynamics and interconnections, ecological thresholds, social-ecological relations, and feedback loops. The system as it is presented in vulnerability studies, on the other hand, is often understood in terms of a unit of analysis such as a human-environment system or a catchment system, or a social group, livelihood, or sector, rather than considered in terms of its component parts and interacting relations. The types of processes and dynamics that are investigated are more likely to be social, political, and economic rather than biophysical and ecological. Resilience research has tended to consider the ecologically bounded scales of the ecosystem, landscape, and region. Vulnerability research, in contrast, tends to consider socially defined scales of the household, community, region, and nation.

- Political ecology and resilience. Peterson uses both political ecology and resilience approaches to examine the political ecology of salmon in the Columbia River Basin (Peterson 2000). He presents a resilience-oriented approach to political ecology that integrates system dynamics, scale, and cross-scale interactions in both human and natural systems. Cote and Nightingale (Cote and Nightingale 2012) comment the concept of social resilience from a political ecology point of view. For them, social resilience work focuses on the functionality of institutions and considers normative issues as outcomes of institutional designs or structures, while normative factors, including power relations and cultural values, are integral to social change and to the institutional dynamics that mediate human environment relations. The extent to which ecological outcomes constitute a problem is a product of politicized, social-cultural processes, emphasizing the positionality and subjectivities of actors involved. Greater efforts at situating definitions and question formulation about resilience within political and cultural heterogeneities helps address this issue and address underlying normative concerns.
- Political ecology, commons and resilience. Armitrage (Armitage 2008) consider that from the commons and resilience literature, normative principles of adaptive, multi-level governance are synthesized (e.g., participation, accountability, leadership, knowledge pluralism, learning and trust). Political ecological interpretations, however, help to reveal the challenge of actualizing these principles and the contextual forces that make entrenched, top-down management systems resilient to change. These forces include the role of power, scale and levels of organization, knowledge valuation, the positioning of social actors and social constructions of nature. Also addressed are the policy narratives that shape governance, and the dialectic relationship among ecological systems and social change. A first point of intersection among several schools involves a shared emphasis on nested hierarchies, levels and scale. A second point of intersection is recognition of possibilities for multiple system trajectories and pathways. A third point of intersection includes an awareness of the self-organization of complex social-ecological systems, despite some difference in emphasis placed on constituent components. Finally, political ecology and resilience converge around the recognition that contextualizing analyses of socio-ecological systems is crucial, particularly where attention is directed at identifying interventions (i.e., governance). The thesis of Armitrage is that continued efforts to engage political ecology with commons theory and resilience thinking offers a way to render less technical, governance of the commons in a multi-level world.

Most of these comparisons are based on what schools include or not. After SETER process our contribution to the debate, based on the issue of change in socio-ecosystems, is the idea that the different schools actually share different models of change but articulate them in different ways.

SETER CONTRIBUTION

From our material we consider that the scholars refer to four different models of change: adaptation mechanisms to hazards and controls, informed actors decisions, patterns of system trajectories, power& control relationships (Table 3).

The adaptation model. Adaptation supposes that an object suffers a stress, an event which can be endogenous or exogenous. This concept has its origins in the natural science, with a specific influence of the evolutionary mode which is based on the reproduction and survival (Smit and Wandel 2006). An individual, a stakeholder group, a social group, an interaction organization can be the research object. The object is exposed to disturbances (it can be hazards, it can be regulations, controls) and this object will respond. The response depends on the adaptive capacity of the object and the impacts will depend on the speed of response. Investigations will be done to understand how much different processes at different levels contribute to the sensitivity of the target entity or its adaptive capacity. Up to this point this approach is shared by the vulnerability school, the biodiversity & ecosystem services as well as the robustness school. The robustness school will in addition consider the feedbacks: to which extent the response will modify the sensitivity of the entity? The resilience school is also partly sharing this approach: it shares the idea that a system is more or less sensitive to disturbances and can switch from a given regime to another regime. As it is impossible to control the perturbations, the logic of the management is to enhance the response capacity. The social component is examined through its adaptive capacity: one will favour the organisation modes, the institutions, the systems of representation which provide a good ability to respond to stress and perturbation.

The incentive structure model. This approach is based on the idea that the one who acts on the resource, on the collective environment is the actor. He is the one who will choose among different options. What is important is to understand the incentive structure which informs his choice. Investigations will be done in order to understand how much different processes at different levels contribute to the definition of the incentive structure. This approach is used by the commons & complexity school across the four case studies. This approach is also used by the political ecology school when trying to understand how much the dynamics at different levels leads to “risk regime”, shifting the costs and uncertainties to farmers, transferring the risk to individual producers. This approach is also the underlying assumption of the “biodiversity & ecosystem services” approach which aims at providing a good assessment of the services for better information and better decision and at identifying the disincentives to provide ES. The social representation and mental models approach tries also to understand what the reasons of the actors’ actions are through the perception of the context.

The system trajectory model. The system can be in different states and the objective is to understand how the system will move from a state to another state. The key point is the transition, the shifts between equilibrium and disequilibrium periods. Is it possible to characterize specific trajectories of the system? The resilience field is engaged in such kind of research on “change”. Scholars have proposed a model of transitions between states and are working on the concept of regime shifts and transformation. It is assumed that the system will evolve from states to states and the important question lies in the trajectory of transitions from one state to another. Information from other levels is integrated, usually through models, either by considering sector variables (economic, ecological, social) or by considering agents, networks and landscapes. The Resilience school has its roots in this approach. It goes beyond the simple systemic approach by proposing a model of a typical trajectory for socio-ecosystem through different phases, and by proposing a model for multiple scales interactions (the panarchical model). Other schools also make use of this approach, metaphorically. For instance political ecologists describe transitions between periods of resource generation vs periods of dissipation,

transitions between periods of accumulation and periods of re-engineering. The management approach associated with this model of change tries to identify a desirable state for the system and use different types of tools to maintain the system in a desirable state or support the transition to a desirable state.

Power & control model. The purpose of the analysis is to describe and explain the social and political relations between different groups of people to understand the control over the resources and the territory. The configuration of relationships between actors and groups will drive the change. There are different models. For some, the history of the relationships will lead to the domination of such or such perspective on the management of the environment. For others, the change lies in the relationship between the technical and economic spheres. Change will occur through the modification of these relationships with or without revealed crisis. Political ecology is the school which unpacks the control structure and explains the power relationships, but one can also consider that the institutional analysis proposed by other schools and inspired by IAD framework (Ostrom 2005) is related to this approach. The difference is that while political ecology looks at the power relations the other schools will look more at the information relations. Commons & complexity focuses on rules on paper and rules in use to see under which condition a group will control the use of resources. Robustness looks at the relationships between resource users, public infrastructures (rules) and public infrastructure providers, this organization being the analytical base to understand the active controls and the alternative controls which could be set.

Intuitively, one would think that the different schools of thought are associated with one of the models of change identified above. Actually, our results show that the scholars holding the flag of a given approach use several models of change. The difference lies more in the articulation of the models of change. The answer to these questions that emerge from our analysis of the diverse responses and treatments of the case studies by “flag-holders” of the diverse schools of thought is that these approaches are first and foremost characterized by a shared conceptual vocabulary. Many if not all the core concepts and analytical concerns on which the diverse human-environment scholars chose to rely for their treatment of the case studies have some equivalent counterpart in the other schools. What sets these different schools of thought apart is more a matter of what we call “conceptual grammar”: the “rules” by which researchers in each of the sub-disciplines tend to organize these elements of conceptual vocabulary. In other words, the schools under scrutiny are differentiated not so much by what they speak of, but rather in what order, or hierarchy, do they tend to rank the importance and/or the sequence of each of these concepts in human-environment explanations. This idea, based on the Bemisia case study, is developed in (Bousquet, Robbins et al. in prep).

When it comes to the issue of management the interventions have to be related to the different models of change. Should the intervention secure the decisions of the individuals, drive the system to a desirable state, play on the domination relationships, or increase the capacity to face perturbations? In an ideal world all of this would be done together, but the tools and the options are often not the same, and an option based on one model of change may not favour the situation according to another perspective. For instance a policy that intends to favour the switch of the system to a desirable state, may not secure the individual decisions. It may also reinforce the domination of some actors on others.

CONCLUSION

Clearly there are the foundations of productive scientific communication and collaboration evidenced by the common language of SETER participants, across historically divergent (and sometimes hotly contested) schools of thought. This shared "vocabulary", though not universal to all researchers in all schools, clearly allows translation between traditions. No SETER researchers were observed to fully and categorically exclude any of these elements, whether these are interactions or system effects, or the play of power between contending actors. In this sense, the glass is "half full" for building diverse research communities and devising cooperative scientific undertakings, and the conclusion of the SETER experiment lead us to encourage such exchange.

There is a temptation, under such conditions, to subsume one way of thinking within another, for example treating common property approaches as a special case of political ecology, or vice versa. This temptation is born of the apparently reasonable goal of producing a united, coherent socio-ecological theory with which to address the grand challenges of global change. This temptation is amplified by the fact that many core elements *appear* to be shared within these approaches. Having said this, the opportunities for mistranslation and disagreement are omnipresent. When the emphasis on differing system elements is changed (putting either power or adaption, for example, at the center of thinking), different, though equally valuable, questions emerge from the mix.

The SETER project suggests that complex socio-ecological interactions are inevitably refracted through parallax conceptual lenses, through which the core element of the images may be the same, but their assemblage dramatically different. Attempting to reconcile these approaches through integration (Gallopín 2006) would be precisely to undermine the core contributions of each mode of thinking. A search for "grand synthesis" therefore, may be analytically destructive.

We conclude from the SETER experiment that more effort should be mounted at cataloguing and more carefully defining the terms, explanatory assumptions, and normative implications of all socio-ecological theory, in an effort to offer some guidelines along which to sort through competing claims. Such an effort to catalogue and coherently presenting not only the intellectual vocabulary but also and mainly the grammar and syntaxes that are emerging within sustainability science is well worth the time and energy that initiatives such as SETER represent.

There is no evidence from SETER, however, to suggest that these approaches are moving in the direction of a single, comprehensive, or universal way of describing, analyzing, and predicting socio-ecological change. Indeed, it would seem the complexity of the emerging novel ecologies of the Anthropocene,

may actually *propel* divergent modes of explanation, becoming the seeds of new competing accounts. Imposing a single explanatory syntax on differing research traditions would only lead to intellectual impoverishment: an effort tantamount to imposing intellectual monoculture that we can ill-afford as we seek to expand, rather than contract, our adaptive intellectual capacity in the next century.

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TABLES AND FIGURES

Table 1. Synthesis on the different schools of thoughts analysis of the four case study.

School of thought	Scientific frame	Methods	Contribution to generic debates
Resilience	Systems analysis, transitions between states, Cross-scale interactions, knowledge & learning	History, comparative analysis, institutional analysis, modelling, scenario analysis	Specific vs generic resilience, tradeoff between efficiency and resilience, relationship between land use heterogeneity & resilience
Commons & complexity	Incentive structures & adaptation in a dynamic context	Surveys, economic experiments, modelling, scenario analysis, role-games	Who loses & who benefits, Risk attitudes & trust, adaptation to policies and environment
Political ecology	History of social & political relationship, Analysis of accumulation & dissipation process, analysis of interactions between knowledge sources, Analysis of actors and territories control	Ethnological approach, social autopsy, historical analysis	Trans-boundary problems & transboundary organizations, States responses to new ecological challenges, Role of capital accumulation, Articulation between public resources and private uses
Vulnerability	Exposure, sensitivity, adaptive capacity	Surveys, archives analysis, experiments	Combination of information both within and across the vulnerability dimensions
Robustness	Resource, resource users, public infrastructure, public infrastructure providers	Any method, modelling	How a system is driven by feedbacks
Biodiversity & ES	Identification of ES flows and their changes due to perturbations	Surveys, measures of ES flows, modelling	How to tune institutions to avoid the alteration of ES,
Social representations & mental models	Settings and compilation of mental models	Document analysis, media analysis, creation of settings, analysis of people reactions	Relationship between settings, representation & action

Table 2. Different System Configurations (indicated as ecosystem phases, economic or social regimes) by Sector in the Four Case Areas.

Case Study	**Sector**	**System Phase or State (A)**	**System Phase or State (B)**	**Slow Variables**	**Fast Variables**
Desert Locust	*Ecosystem*	Solitary Locust	Swarm Phase	Habitat Soil Moisture	Rainfall Chemicals Temperature
	Economics	Control using Pesticides	No Control	Price of Oil Infrastructure for delivery	Pesticides
	Social	International Network	Regional/Country Institutions	Agreements Monitoring	Swarm Information
Greenhouses Tomato, **Bemisa**	*Ecosystem*	TYLC outbreak	No TYLC	White Fly Populations	Temperature
	Economics	Tomato Production	Other Crops	Markets National Policy	Profit Margin
	Social	No compensation for disease losses	National compensation	Political power of Farmer groups	Quarantine declaration
Sahel Fuelwood	*Ecosystem*	Savanna Vegetation	Desert Vegetation	Climate -Rainfall Land Use Patterns	Droughts
	Economics	Central Management	Local Markets	National Institutions	Desertification Crisis

	Social	Forest Administration	Woodcutter Associations	Energy Source/Type	
Camargue	*Ecosystem*	Reed Beds	Lakes (open water)	Hunting Economics Water Management Infrastructure	Freshwater levels
	Economics	Wheat Production	Rice Production	Soil salinity Sediment Input	Freshwater Input
	Social	Iconic Cultural Landscape	Low cultural value	Bulls, Horses, Flamingos	

Table 3. The models of change in human-environment analysis. The cells under "levels at which change is apprehended" indicate the type of action. An empty cell indicates that the driver of change is not considered at this level but processes at these levels are considered as contextual.

Model of change	**Level at which change is apprehended**					**Role of the analyst: to identify the …**	**Finality of the associated management interventions (if any)**
	Actor	**Group of actors**	**Social groups**	**Interaction organisation**	**Biophysical & ecological environnement**		
Incentive structure (I)	choose					incentive structure and document it	To orient (secure) the actors' decisions
System trajectory (S)				Evolves		components & their interactions	To orient toward desirable states
Adaptation (A)	Responds	Responds	Responds	Responds	Responds	exposure, sensitivity & adaptive capacity	To decrease exposure and sensitivity, increase adaptive capacity
Power & control (P)				Controls		Social & political relationships	To modify the control organization

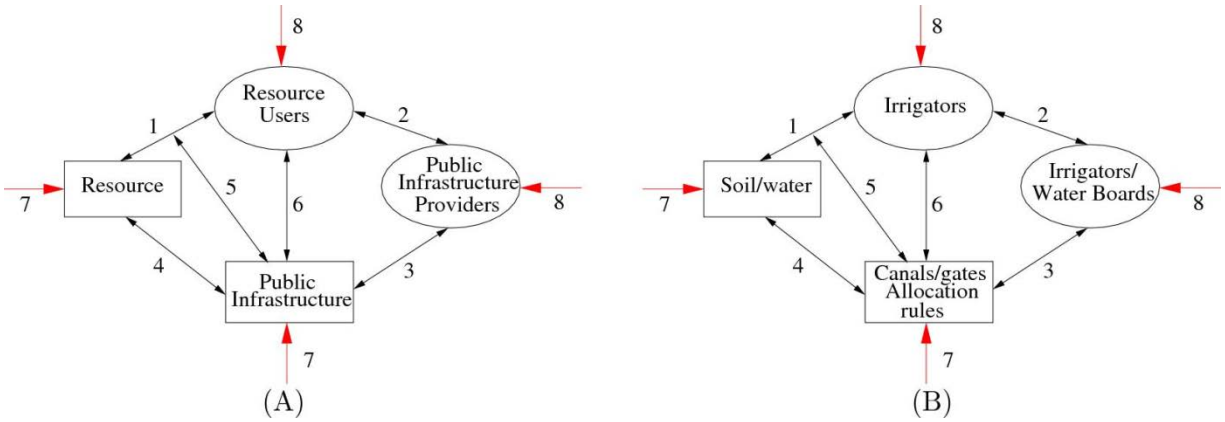

Figure 1: (A): General robustness framework (adapted from Anderies et al., 2004). (B): Specific instance of the framework for an irrigation system. Ovals indicate the social components of the system and the boxes represent physical and constructed portions of the system (which may be a combination of physical entities and institutional arrangements). Black arrows indicate relationships between these components while red arrows indicate potential shocks to the system.

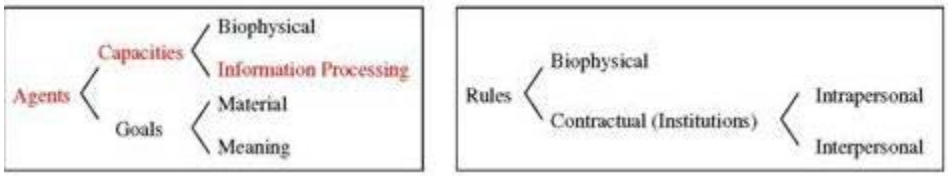
Agents
Capacities
Biophysical
Information Processing
Goals
Material
Meaning
Rules
Biophysical
Contractual (Institutions)
Intrapersonal
Interpersonal

Figure 2

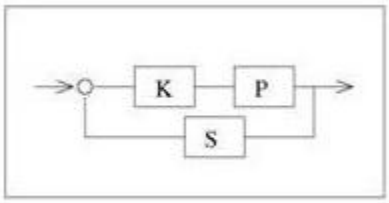

Figure 3. P is the plant (resource), K is the control, the policy and S is the sensing.

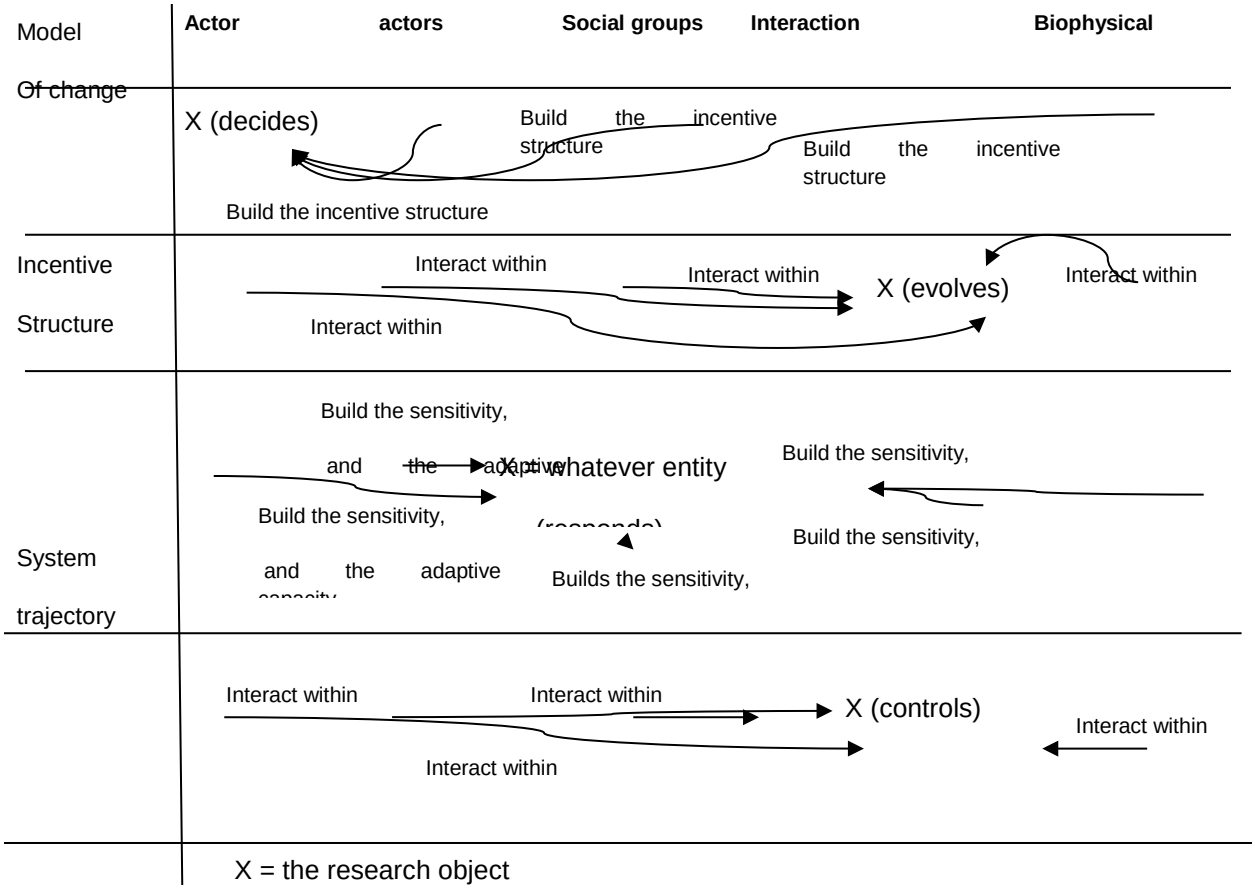
Model
Of change
Actor
actors
Social groups
Interaction
Biophysical
X (decides)
Build the incentive structure
Build the incentive structure
Build the incentive structure
Incentive
Structure
Interact within
Interact within
X (evolves)
Interact within
Interact within
System
trajectory
Build the sensitivity,
and the adaptive
Build the sensitivity,
and the adaptive
Builds the sensitivity,
Build the sensitivity,
Build the sensitivity,
Interact within
Interact within
X (controls)
Interact within
Interact within
X = the research object

Figure 4

APPENDIX 1. THE SCHOOLS OF THOUGHT INVOLVED IN SETER PROJECT

This appendix proposes a short synthesis on the different approaches which are considered as schools of thoughts by the SETER project. Each of these schools of thought would deserve a much longer description: references of key papers, books and text books are given. Furthermore, the description varies with the different scholar's points of views. For this reason we indicate below the authors of these descriptions. They are all members of the SETER project.

POLITICAL ECOLOGY (D. GAUTIER & M. CASTRO)

Political Ecology (PE) – as a research school of thought – emerged from the 1980s as a way to acknowledge the multiple character of environmental issues and phenomena, not only in their ecological aspects, but also in their political, economic and social aspects. Political ecology proposes an integrative approach for doing inter/transdisciplinary research. By studying its research object through the lenses of several disciplines, PE stands out as a scientific, intellectual and ethical way of thinking between, across and beyond all disciplines. Though primarily rooted in critical geography, PE calls different disciplines to interact in order to change and enrich themselves. Political ecologists do not satisfy themselves of studying local communities through the use of natural resources. Further on, they explore the power relations among the multiple actors, acting at different scales. They get a close look to knowledge and practices of social actors. This school of thought raises questions about the place that diverse actors in environmental management (users, managers, researchers) give to the politics and policy.

By the 1970s, the term political ecology (PE) was being used by scientists to refer to research addressing the relationship between environmental science and environmental policy. The first contributions to PE were Marxist critiques of malthusianism. This field of research combines human cultural ecology -which explores the multiple relationships between human societies and their biophysical environments- with political economy -that examines the power relationships between actors (Peet and Watts 1996; Robbins 2004). Since then, several disciplines, including anthropology, sociology, geography and political science, have referred to PE as a school of thought integrating political economy and cultural ecology to analyze environmental management issues. By focusing on factors explaining power relations between different groups of people and putting together the complex nature-society premises with global processes, PE produces research that challenges the prevailing interpretations of the causes and consequences of environmental degradation as well as the solutions to these problems.

According to Paulson et al (Paulson, Gezon et al. 2003), political ecology was developed around a set of key ideas: 1) the idea that use of and access to resources are organized and mediated by social relationships that might impose a production rhythm that might be harmful to the environment (Watts 1983); 2) the recognition of different positions, perceptions, interests and rationalities in relation to the environment: "one person's profit may be another's toxic dump" (Blaikie 1985); 3) the idea of connectivity across scales, which implies that local processes are influenced and influence global processes (Escobar 1996; Escobar 1999); 4) the idea that social exclusion is the result of political

economic and ecological processes mutually reinforced: "land degradation and is both the result and a cause of social marginalization" (Blaikie and Brookfield 1987).

Based on the work of (Peet and Watts 1993; Blaikie 1999; Stott and Sullivan 2000; Forsyth 2003; Zimmerer and Bassett 2003; Peet and Watts 2004; Robbins 2004), we can identify two main currents within PE. The first comprises empirical work on environmental activism related to struggles for resources and the formation of the state. This type of research provides a thorough analysis of environmental resistance of certain social groups (Blaikie 1985; Bryant and Bailey 1997; Bryant and Goodman 2008). However, this type of work is less attentive into questioning some definitions associated with ideas of environmental degradation and how these definitions are built. The second approach involves research about the construction of the environment as a discourse and the role of discourse and political action in the establishment of accepted definitions (Watts 1983; Peet and Watts 1996; Peluso and Watts 2001). This approach helps to understand the driving forces behind policy making, but the physical reality of environmental problems that operate beyond human activity tends to be less well addressed. However, some political ecologists give an important place to study the biophysical facts and their relations with the sociopolitical conditions that accompany it. (Zimmerer and Bassett 2003) proposed to work around socio-environmental interactions rather than on what they call "environmental politics" or "politicized environments". Thus, these political ecologists conduct studies focusing on hybrid concepts involving both biophysical and social changes, crossing biophysical and social sciences (Turner 1999; Turner 1999; Bassett and Zuéli 2000).

Since the mid-90s, PE has taken a poststructuralist turn. Influenced by Michel Foucault's thought, and partly inspired by the work on "hybrid science" of Bruno Latour (Latour 1999), some political ecologists have emphasized the study of the historical development of environmental discourses. This PE is defined by the study of the genealogy of dominant environmental discourse (environmental narratives) and the identification of power relations associated with these discourses. PE not only identifies winners and losers in a particular environmental struggle, but it analyzes the political struggles behind the establishment of an environmental discourse defined as a “truth”, as well as the social and institutional factors that define it as such. Post-structuralist political ecology proposes first to separate the biophysical processes from the significance that different actors attribute to it, and second, to analyze the translation process of the biophysical fact to an institutional fact. The aim of this "hybrid science" advocated by political ecologists is to indicate the distance between the universal and hegemonic discourse on environmental issues and the experience of people in specific localities in relation to particular biophysical facts.

VULNERABILITY (C. POLSKY)

Vulnerability has emerged in recent years as one of the central organizing concepts for research on global environmental change (Schroter, Polsky et al. 2005; Downing 2000). Vulnerability is defined as the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation or stress, accounting for adaptive capacity. The vulnerability school of thought demands attention to human-environment interactions along three dimensions: exposure, sensitivity, and adaptive capacity. A coupled human-environment system is considered vulnerable only if it is exposed and sensitive, and also possesses limited adaptive capacity. This use of

the term vulnerable therefore differs slightly from the colloquial use. In this way, for example, the river delta-city system located in New Orleans, Louisiana (USA) is considered vulnerable to the effects of tropical storms not because of the deaths and damages inflicted by Hurricane Katrina in 2005, but because the system has experienced such storms -- and impacts -- for centuries, and yet has not built a system that produces fewer damages from such storms. In fact, one could argue that damages per storm are increasing in recent decades, despite massive technological interventions. Thus the damages from the next tropical in the New Orleans region storm may equal or exceed the damages from the 2005 event, suggesting a systemic vulnerability. This conceptualization does not minimize the suffering from the damages experienced in 2005; instead, it shifts the focus from the immediate damages to the long-term view about the system's ability to learn from the past to produce a sustainable system for the future.

In general terms, the three vulnerability dimensions are defined as, respectively: the intersection of the hazard with the exposure unit; the short-term impacts/responses & conditions mediating the production of the impacts following the exposure; and the current/future abilities to implement effective, long-term responses to the impacts. These dimensions are not necessarily independent in all cases. To operationalize these dimensions – i.e., to transform the abstract concepts into concrete measurements for analysis – it is first necessary to specify "vulnerability *of what* and *to what*." Specifying *of what* is equivalent to specifying the exposure unit, i.e., the socio-ecological system to be studied, delimited by geography and time. Specifying *to what* is equivalent to specifying the hazard(s), i.e., the one or more stresses threatening the socio-ecological system. This specification may appear so obvious as to be unnecessary to state. However, arguing here for the importance of this specification serves the important function of highlighting the fact that a set of human-environment interactions may produce vulnerabilities at one spatial or temporal scale or for one stakeholder group but not at a different scale or for a different stakeholder group. Thus the "answer" about what produces/attenuates vulnerability for a given case may vary with the particular specification of the exposure unit and hazard(s) to be studied in a given vulnerability assessment.

This concept is appealing because it is inclusive. From this perspective, humans and the natural environment are not independent systems, homogeneous and unable to adapt to threats, be they anticipated, realized, or perceived but not realized. Instead, human and natural systems are viewed as intimately coupled, and potentially differentially exposed, sensitive, and adaptable to threats. This logic, followed to its natural conclusion, means that adopting a ''vulnerability'' perspective for a given case might require a thorough investigation of many dimensions (e.g., biophysical, cognitive, social) of human–environment interactions. Strictly speaking, therefore, to conduct vulnerability assessment means that no element of the human–environment system may be simplified away or considered a mere boundary condition. This conceptual inclusiveness complicates the analytical task (compared to the simpler impacts-only approach), which partially explains why there are few, if any, studies that deeply engage this vast set of intellectual dimensions. This inclusiveness also raises important methodological questions. Schroter et al. (2005), propose that researchers will capture the vulnerability perspective if they adopt an overarching approach comprising eight general steps (Fig.A.1.1).

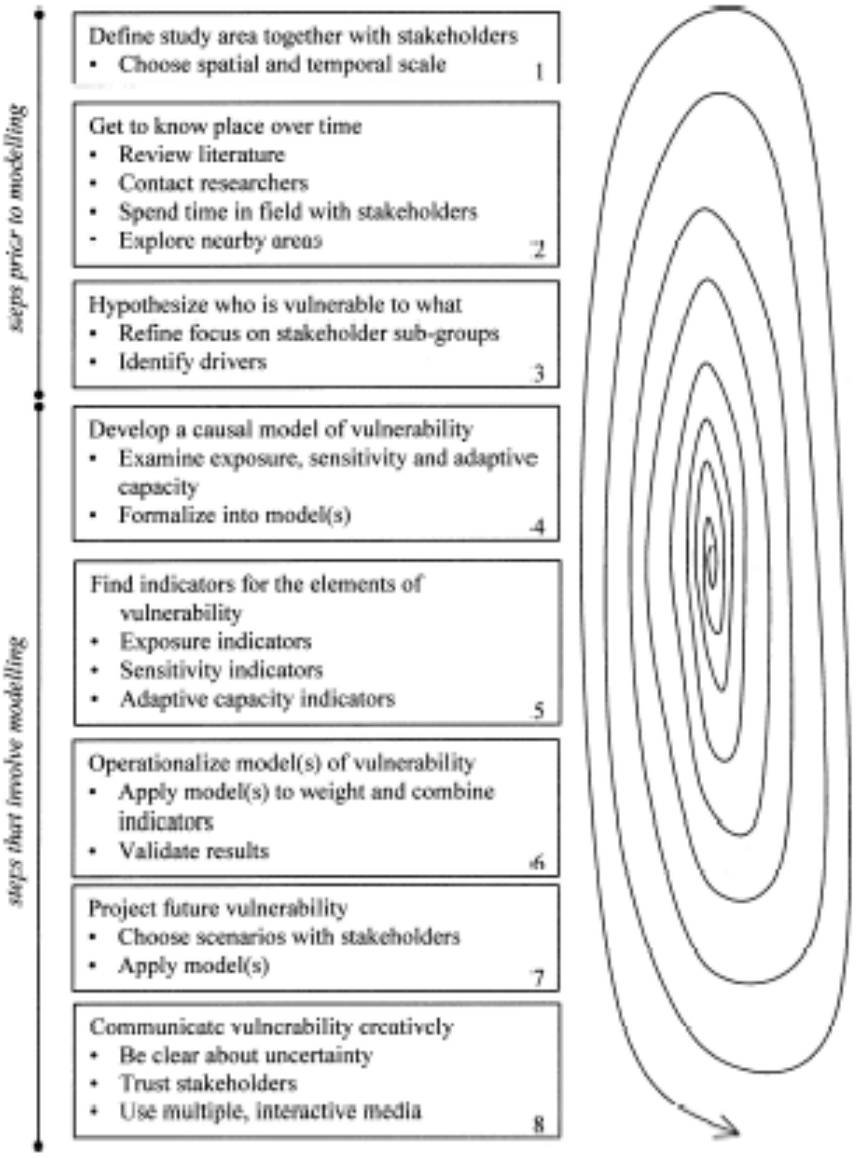

Figure 1. **An eight step method for global change vulnerability assessments.**

Figure A.1.1 an eight step method for global change vulnerability assessments (Schroter, Polsky et al. 2005)

The frame for vulnerability assessment that was used during SETER project is composed of seven questions:

- Overarching Research Question: What explains the vulnerabilities of the [exposure unit] associated with the [hazard(s)]?
- Exposure unit: The [socio-ecological system] to be studied, delimited by [geography] and [time]
- Hazards: the one or more [stresses] threatening the socio-ecological system
- Units of analysis: the [objects] in the exposure unit to be sampled for study

- Exposure: description of the [intersection] of the hazard with the exposure unit
- Sensitivity: the [short-term impacts/responses] & [conditions] mediating the production of the impacts following the exposure
- Adaptive capacity: current/future [abilities & inabilities] to implement effective, long-term responses, determined in part by an understanding of previous impacts/responses

RESILIENCE (L. GUNDERSON & A. QUINLAN)

The resilience perspective emerged from ecology in the 1960s and early 1970s through studies of interacting populations like predators and prey and their functional responses in relation to ecological stability theory. Ecologist C.S. Holling in his paper on resilience and stability in ecological systems illustrated the existence of multiple stability domains or multiple basins of attraction in natural systems and how they relate to ecological processes, random events (e.g. disturbance) and heterogeneity of temporal and spatial scales (Holling 1973). With this new perspective research has shifted the focus to transitions between the stability domains and emphasizes variability and system dynamics rather than stability. Holling introduced resilience as the capacity to persist within a stability domain in the face of change and proposed that ‘‘resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist’’ (Holling, 1973, p. 17). Early applications of the findings were generated from the resource ecology group at University of British Columbia, particularly in relation to the insect spruce budworm and its role in boreal forest dynamics of North America (Ludwig and Holling 1978), followed by examples from the dynamics and management of rangelands (Walker, Ludwig et al. 1981), freshwater systems (Fiering 1982) and fisheries (Walters 1986). Applied mathematics, modeling and applied resource ecology at the scale of ecosystems were combined with inductive science and experience from field work and large scale management disturbances. (Folke 2006)

To understand system dynamics one has to differentiate the slow and fast driving variables (figure A1.2) (Holling 1986)**.** Folke an co-authors, presented a synthesis on this aspect showing that the combination of an alteration (slow variable often) triggered by an event make the transition to another regime (Folke, Carpenter et al. 2004).

The System	**Fast Variables**	**Intermediate Variables**	**Slow Variables**
Forest insect outbreak	Insect	Foliage	Trees
Forest fire	Ignition	Fuel	Climate

Fishery	Phytoplankton	Zooplankton	Fish
Savanna	Grasses	Shrubs	Herbivores
Disease	Disease organism	Vector and susceptible	Human population

Figure A.1.2 Types of variables for different ecosystems

Following many years of interdisciplinary research new theoretical models were proposed (adaptive cycle, panarchy) and the definition of resilience has evolved. The adaptive cycle was an important step in the history of resilience thinking because it represents different phases of cyclical change that are common to many social-ecological systems (figure A1.3).

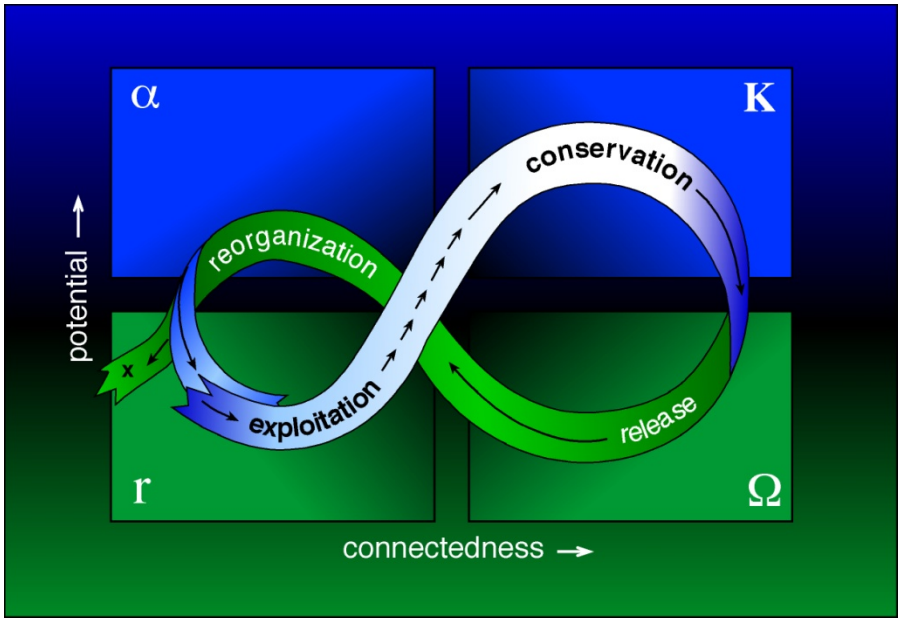

Figure A.1.3 The adaptive cycle.(Holling 1986)

Generally speaking, the progression from an r to K phase is driven by the initial exploitation of resources and slowly changing variables that gradually lock up resources and reduce a system's flexibility. The release (Ω) phase is triggered by disturbance and the reorganisation phase (α) involves the relatively rapid reorganization of the system, sometimes but not always, into a new regime. Briefly, the panarchy

model expands on the adaptive cycle by introducing hierarchy theory and the notion of nested adaptive cycles, where system dynamics at one scale interact with those at higher and lower scales.

Following Carpenter et al. (Carpenter, Walker et al. 2001) social–ecological resilience is interpreted as (1) the amount of disturbance a system can absorb and still remain within the same state or domain of attraction, (2) the degree to which the system is capable of self organization (versus lack of organization, or organization forced by external factors), and (3) the degree to which the system can build and increase the capacity for learning and adaptation. More recently there is an increased emphasis on transformability i.e., the capacity to cross thresholds into new development trajectories, as well as emerging insights into how transformation at smaller scales in the panarchy can enhance resilience and capacity for transformational change at larger scales (Folke, Carpenter et al. 2010).

An emphasis on transformability broadens the focus in social–ecological research to include adaptive governance (Dietz, Ostrom et al. 2003) in order to explore the broader social dimension that enables adaptive ecosystem-based management. An adaptive governance framework relies critically on the collaboration of a diverse set of stakeholders operating at different social and ecological scales in multi-level institutions and organizations.

COMMONS & COMPLEXITY (M. JANSSEN)

The study of collective action for the management of natural resources goes back to Gordon (Gordon 1954) on the difficulty on governing shared resources. The use of rational choice theory explains the observed demise of many commons, such as ocean fisheries, forests, ground water etc. The conventional theory assumed a very simple model of human behavior that makes strong assumptions. Individuals are assumed to have complete information of the situation they are in, including the preferences of others. Furthermore, they were assumed to maximize the material payoff to themselves. People are trapped and cannot solve collective action problems. A consequence of this simplistic theory was that the only type of solutions has to come from outside, such as privatizing property rights or enforcing use constraints. If such an intervention was not imposed a tragedy of the commons was to be expected, a concept popularized by Garrett Hardin (Hardin 1968).

But, scholars from many disciplines reported examples of long-lasting success cases of communities who solved collective action problems. In 1985 a meeting was organized by the National Research Council to synthesize the empirical evidence (NRC 1986). Since then the study of the commons is an international collaborative effort of different disciplines using different methods. Besides finding that self-governance does happen, and often lead to better results than imposed regulations, scholars start to develop a better understanding of the factors that contribute to success of collective action (Ostrom 1990). Ostrom and her colleagues developed over the years a framework that include more explicitly current understanding of human behavior, micro-situational variables and broader context (Poteete, Janssen et al. 2010).

The general frame is the dilemma between individual and group interests. The group interest would be to cooperate while individuals' interest is to free ride on effort of others. Institutional arrangements provide incentives to stimulate individuals to contribute to the common good, monitor outcomes and enforce rule breaking. Although this school considered every case as unique, there is a need to have a

framework that is general but recognize the complexity. Among others, a set of papers in a recent issue of PNAS (Going beyond panaceas) focused on the problem of fit between ecological dynamics and institutional arrangements(Ostrom, Janssen et al. 2007). The question is: how do appropriators craft institutions and what helps them to fit it to the social-ecological context? Poteete, Janssen and Ostrom produced a framework proposing different core relationships in social dilemma (Fig. A.1.4).

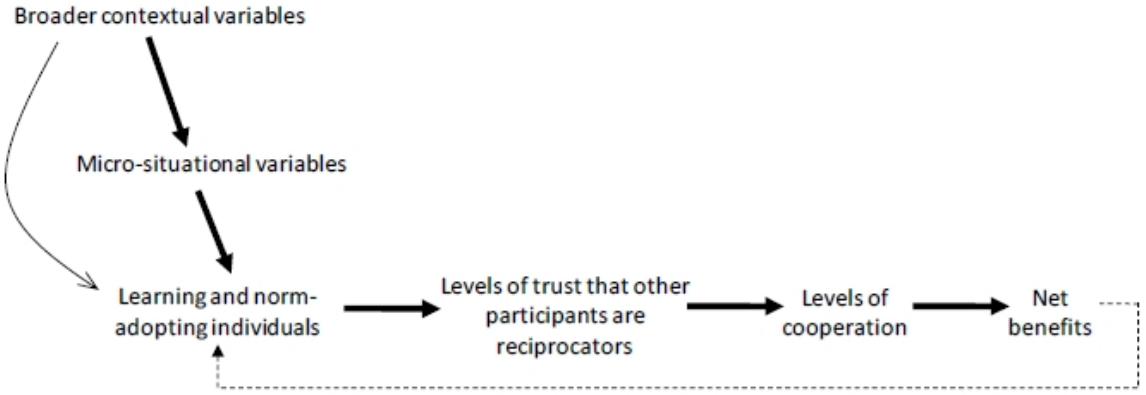

Fig A.1.4 Micro-situational and broader context of social dilemmas affect trust and cooperation (Poteete, Janssen et al. 2010)

In behavioral theory, cooperation in social dilemmas depends on individual differences and context. The set of micro-situational variables that affect trust and cooperation are represented in the figure below (Fig. A.1.5).

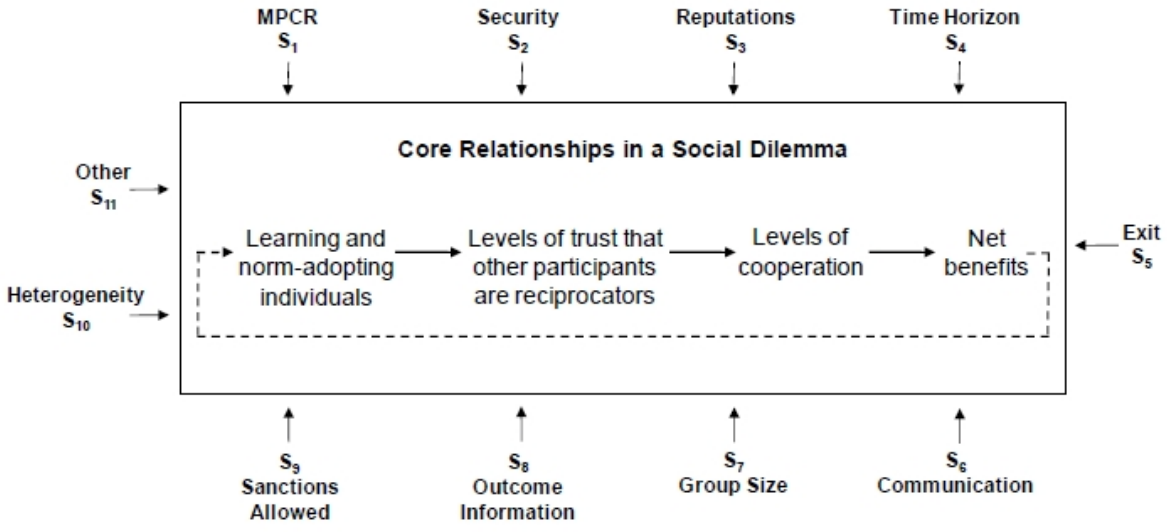

Fig A.1.5. Micro-situational variables affecting trust and cooperation

Based on comparative analysis of many case studies we can identify broad categories of resource systems with mobile resources (water, fisheries, pastoralism) non mobile resources (forests) and

resource systems with buildup infrastructure (irrigation systems) (Schlager 1994). Many types of institutional arrangements (transhuman, nomadic) varying from Swiss Alps to Kenya and India revealed to be adapted to spatial variability of rainfall. The problem is often that current trend on privatization leads to mismatch of social and ecological dynamics.

Concerning the adaptation to variability, there is high investment to coordinate activities of provision and extraction. Many social-ecological systems are adapted to particular variability regimes. These systems are robust, yet fragile to a change in variability regimes, such as effects of globalization. Comparative over-time analysis of forest management (more than 40 forests are visited at least twice using the same methods of measurement and analysis) Ostrom E, Nagendra H (Ostrom and Nagendra 2006) show that all institutional arrangements have examples of success and failure. The main red line in examples of success is the involvement of at least one user group in regular monitoring of conformance to the rules related to access and use patterns is significant.

The analysis of case studies follows a diagnostic approach (Ostrom 2007) where initially broad themes of social and ecological components of the social-ecological system are investigated before digging deeper into the specific attributes of the system. The complexity of the system is caused by the complex interdependencies of the attributes of the system at different levels of scale. Although each case is unique, we can formulate stylized findings that can be replicated in controlled experiments, such as the importance of communication, trust and ability to contribute to the crafting of rules (Poteete, Janssen et al. 2010). Concerning the rules, they are defined as shared understanding about enforced prescriptions, concerning what actions (or outcomes) are required, prohibited, or permitted. A difference is distinguished between rules in use vs rules on paper and between formal rules vs informal rules (formal rules have explicit consequences defined for when the rules are broken (sanctions) and can be enforced by a third party).

ROBUSTNESS AND CONSERVATION OF FRAGILITY (M.ANDERIES)

In the context of SESs, model analysis has frequently been conducted using optimal control techniques (Stiglitz 1974; Forster 1975; Clark 1976; Clark and Kirkwood 1986; Lucas 1988; Barro and Sala-I-Martin 1995; Beltratti 1997; Amouzegar and Moshirvaziri 1999; Kawaguchi 2003), and have generated a series of interesting insights. However, formidable mathematical challenges typically limit these analyses to very simple situations. Such simplification is not necessarily a problem provided that the results such models generate are properly interpreted as general *policy goals* rather than practical policy prescriptions. This observation suggests that additional tools are required to address policy implementation questions.

Two related streams of thought have emerged in the resource management and ecological literatures regarding policy implementation: adaptive management (Walters 1986) and resilience-based management (Holling 1973; Holling 1986; Ludwig, Walker et al. 1997; Gunderson and Holling 2001). These schools of thought emphasize learning through management experiments and developing the capacity to cope with unforeseen shocks and change. At the same time, the field of robust control (Zhou and Doyle 1998) has been developing management tools for highly uncertain systems. Ideas from robust control have made their way into economics, mainly in the area of macroeconomic policy (Kendrick

2005; Hansen and Sargent 2007) but focus on linear models and linear quadratic regulator (LQR) theory. Likewise resource management problems have begun to receive attention in the engineering literature. Although focused more on optimal control (Belmiloudi 2005; Belmiloudi 2006) or the bifurcation analysis of feedback control systems (Dercole, Gragnani et al. 2003), this recent work is suggestive of the potential for synergies between the two fields. Finally, robustness ideas have appeared in the management science literature recently (Lempert and Schlesinger 2000; Lempert, Groves et al. 2006)(Lempert et al., 2006; Lempert and Schlesinger, 2000). Lempert et al. (Lempert, Groves et al. 2006)present a method for robust decision making by calculating the minimum maximum regret for a set of strategies against different futures.

The Robustness in SES approach incorporates threads from all these literatures. As such, it is critical to make some distinctions as perspectives on control differ considerably between disciplines. In economics, it is typical that controller design methodology and some concept of robustness are implicit in an objective functional that is based on some economic rationale. For example, in macroeconomics, robust control is often framed in terms of a dynamic game between nature and the policy maker whose objective is to maximize the minimum expected value of a policy choice (maxi min problem). This objective implicitly defines a design methodology and a concept of robustness (i.e. minimize the sensitivity of the system to uncertainty about nature). In engineering, on the other hand, design methodology and performance measures can be somewhat more divorced. As mentioned in the introduction, engineers may construct controllers based first on their stability properties, ability to reach particular system states, and noise attenuation properties (note that the optimal control fails in this regard). These controllers are then tuned to meet some performance objective and sensitivity criteria that are defined separately.

Some notion of optimality is used to set a policy goal based on the traditional economic rationale of maximizing the social welfare generated by a resource. Implementable policies that attempt to come as close as possible to optimality, yet are less sensitive to parametric uncertainty and sampling issues. Finally, we define a sensitivity measure to assess how performance deteriorates due to uncertainty. The main objective of this analysis is to (i) determine whether it is possible to develop practical management strategies with general robustness to parameter variations that yield reasonable performance, (ii) shed light upon underlying fundamental robustness-performance-vulnerability trade-offs, and (iii) provide some social, institutional, and economic intuition for the results.

In order to connect the case studies and formal models, the framework developed by Anderies et al. (Anderies, Janssen et al. 2004) (Figure A.1.6(A)) which highlights relationships between groups of actors and biophysical context is used. Ovals indicate the social components of the system and the boxes represent physical and constructed portions of the system (which may be a combination of physical entities and institutional arrangements). Black arrows indicate relationships between these components while red arrows indicate potential shocks to the system. Figure A.1.6 (B) shows a specific instance of a general SES shown in (A) for an irrigation system.

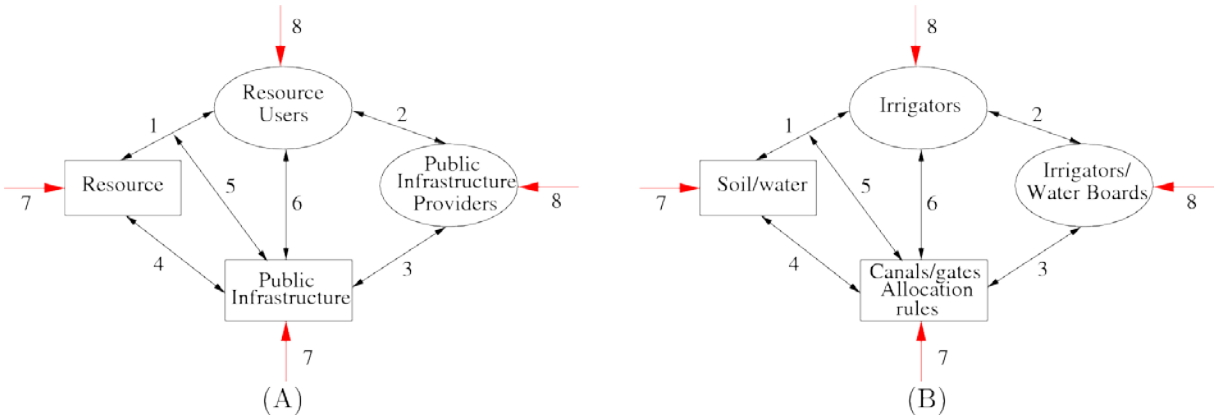

FIGURE A.1.6: (A): GENERAL ROBUSTNESS FRAMEWORK (ADAPTED FROM ANDERIES ET AL., 2004). (B): SPECIFIC INSTANCE OF THE FRAMEWORK FOR AN IRRIGATION SYSTEM.

For example, the main resources in an irrigation system are soil and water. They generate direct benefits in securing food supply and income for irrigators and indirect local benefits by creating demand for supply services such as fertilizers, seeds, pesticides, and transport. The shocks important to the resource (red arrow, type 7) are strongly related to climate change. Less predictable and more extreme variation in temperature and water availability make planning farm operations more difficult, increase the chance of crop failures and will likely threaten food security for the world's most vulnerable people. Public infrastructure in irrigation systems includes the canal system itself and flow control features. Less obvious, but equally important, is institutional (the rules that govern the use of the canal system and collective choice, etc.) and social infrastructure (trust, reciprocity, power relationships, etc.). The operation of this component of the system depends on the interaction of several contextual variables including political and economic conditions and climatic shocks (e.g. floods). Resource users consist mainly of the irrigators themselves and their families. They are subject to a wide range of potential shocks (red arrow, type 8). Industrialization, urbanization, growing populations and environmental concerns all exert pressure on irrigators. As multiple sectors in a rapidly expanding economy compete for scarce water, the logic of water pricing can change. A shift in agricultural labor to other sectors in the economy can also generate stress on the operation of small-scale irrigation systems.

Just as important to the operation and robustness of SESs as the fundamental components just described, and perhaps more so, are the feedbacks between them (links 1-6). As these feedbacks develop both in response to basic operational needs that require links between the basic components and in response to exogenous shocks, they may induce directional endogenous change in the nature of the basic components and the links themselves (Anderies, Rodriguez et al. 2007; Janssen and Anderies 2007; Janssen, Anderies et al. 2007). Understanding the effect of these adaptive, endogenous dynamics on a system's capacity to cope with changing context and new classes of disturbances is the focus of the robustness-vulnerability trade-off analysis conducted here.

Using a fleshed out version of the skeleton in Figure 7(B) based on the details from the SES of interest, it is possible to develop models that captures the basic relationships between human actions, resources, and how they are mediated by physical infrastructure. The models fall between simple models aimed at

theory development (Gordon 1954; Clark 1976) and detailed models which focus on fine scale aspects of a specific system. Models are used to explore how spatial and temporal structuring of interactions between resource users forced by physical infrastructure (link 6) conditions the relationship between resources and physical infrastructure (link 1) and, in turn, impacts institutional infrastructure (link 5). By analyzing several different institutional regimes associated with shocks to the resource and infrastructure, we explore how the system, especially links 1, 5, and 6 and the components they connect, may become well-adapted to these shocks (type 7). Finally, we use the framework to explore the implications of this particular adaption for the link between public infrastructure providers (e.g. government agencies, etc.) and the rest of the system (links 2 and 3) and the capacity of the system as a whole to cope with novel change.

This analysis, although very powerful, is necessarily limited. Numerous informal social processes that may add flexibility to the system may not be captured. This is due to practical limitations of our capacity to extract meaningful insights as model complexity increases. This approach can, however, reveal how such unmodeled social processes may relate to our results. Finally, it is important to note that this approach does not seek to develop models to *fit* data from a particular case. Rather, models are *motivated* by and capture only the *key features* of the SES of interest. Models are used to 1) *compare* the performance of different institutional arrangements for resource allocation and management under different assumptions about the nature of the resource and 2) *compare* these institutional arrangements to those that the resource users actually follow in different circumstances. This analysis allows the analyst to explore the *fit* between physical infrastructure, behavioral characteristics of actors, and resource dynamics.

BIODIVERSITY & ECOSYSTEM SERVICES (M. ANTONA, C.PERRINGS & A.KINZIG)

The biodiversity and ecosystem services approach contributes to the "problem-driven"sustainability science, which aims to "change the way science of human use and impacts on environment is being done" (Perrings 2007). Two of the key issues for sustainability science are uncertainty (on the structure of the socio ecological system and the measure of its performance) and learning in the decision process.

The focus on ecosystem services (ES) as describing the human nature linkages can be related to several origins. One refers to nature's services by ecology scientists in the end of the 70's -such as Westman (Westman 1977) or Erlich and Erlich (Ehrlich and Ehrlich 1981). These scientists developed conservation literature to address the issue of extinction of species, and the design of conservation devices. A second one is the ecological economics school which aimed to consider natural regulation in economy-environment linkages. This fructuous field of research challenged the discipline-base resource economics and its rules of substitution of various forms of capital (including natural capital). Ecological economics introduced the notion of threshold limiting this substitution and developed the system dynamics modeling in economics (Costanza, Wainger et al. 1993). In the 90's EE developed the economics of biodiversity to consider ecological processes, which underlay the resource base. According to biodiversity economics, threats on biodiversity occur because full benefits and costs of biodiversity uses are not fully taken into account in decision making process. This led to the development of monetary valuation of natural of biodiversity, the values provided by biodiversity to society being an aggregation of direct and indirect use values (eg direct as fuelwood, food and indirect as species habitat or watershed protection) and non use values (eg., cultural heritage) (Perrings, Naeem et al. 2010). The concept of ES as benefits to society mixed all these influences. While economists would, as a matter

of course, identify the preferences and values different people place on different ecosystem services, ecologists would more often simply “make up” a list of important services (using expert knowledge, albeit of a particular sort). This concept emerged in the scientific arena in 1997 with global studies identifying the importance of nature’s services (Daily 1997) and « the value of the world’s ecosystem services and natural capital » (Costanza, d'Arge et al. 1997)(Costanza et al.1997). The concept of ES was put into the political agenda with the Millennium Ecosystem Assessment (MEA) report (Millennium Ecosystem Assessment 2005) and the MEA framework, a pluridisciplinary attempt to represent the way ecological and economic processes interact. The MEA combines the advancements of ecological economics with the knowledge of functional ecology for producing a set of questions to be answered in order to):

- Identify options that can better achieve core human development and sustainability goals
- Better understand the trade-offs involved (across sectors and stakeholders) in decisions concerning the environment
- Align response options with the level of governance where they can be most effective. The MEA framework differentiates different types of services (fig A.1.7) and was mainly interested in the identification of physical flows of ES and their evolution.

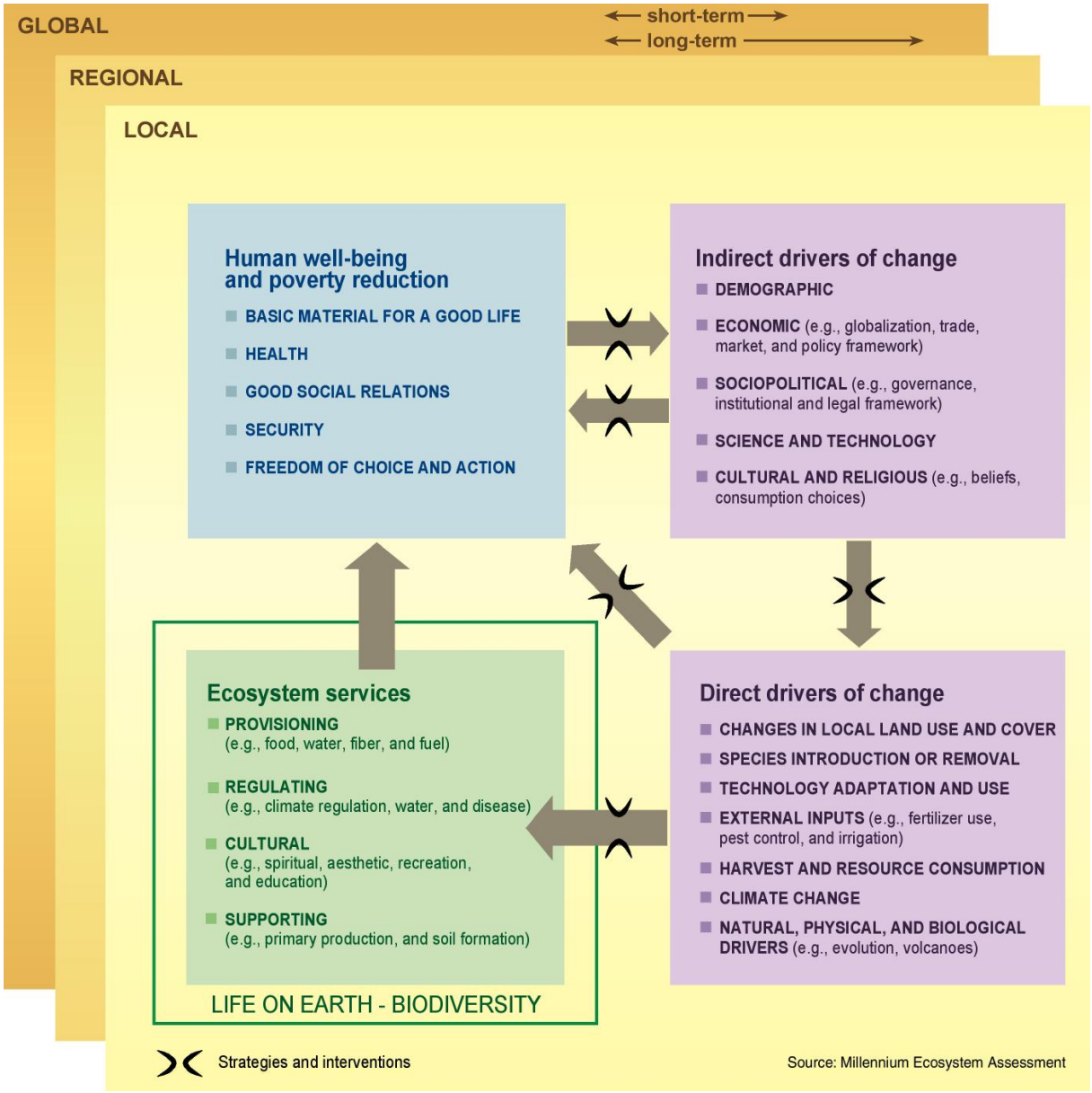

Fig A.1.7 Millenium ecosystem assessment framework (Millennium Ecosystem Assessment 2003)

"The Millennium Ecosystem Assessment has changed the way that we think about the interaction between social and ecological systems. By connecting ecological functioning, ecosystem processes, ecosystem services and the production of marketed goods and services it has identified ecological change as an economic problem. It has also drawn attention to a new dimension of the environmental sustainability of economic development" (Perrings, Naeem et al. 2010). For some authors, the outcome of the MEA was to improve the understanding of linkages between biodiversity, ecosystem functioning, various ecosystem services and human well –being, as well of linkages between human behavior and biodiversity loss.

Building on this framework, the BD&ES approach questions the assertion of positive linkages between biodiversity and the various ES, by focusing on necessary trade-offs to obtain both conservation of biodiversity, flows of ES and human development, and on the decision problem. As stated by Perrings,

there is still “difficulty to predict the consequence of alternative strategies for managing changes in biodiversity”.

The trade offs

Ecosystem trade-offs can be identified between biodiversity and ES. Ensuring flows of ES can threaten and decrease biodiversity, challenging the idea of a positive relationship between biodiversity and ES, then the nature of the conservation and management policy. Some biodiversity components are also sources of disservices to human society (e.g. diseases, mosquitoes and locusts…). Policies and strategies based on the ES approach can be opposite to conservation policies and strategies. There is then a need to have twofold management of nature: conserving biodiversity and focusing on the main ES. The ES approach involves a coordination of management scales, allowing more voices to participate to the decision-making process.

Ecological change as a decision problem

Decisions on ES (and on biodiversity) are not based on physical flows of ES but on their importance for society (moral value; spiritual obligation; …), and on the benefits they produce. This value can be decreasing even with constant flows on ES. The values granted to ecosystems depend on their capacity to provide ES as benefits in the future. The economic problem is then set. If provisioning services are considered in the decision making process, because market price of ES can be a measure of the value of ES benefits in few specific cases, there is no good indicators of value for the full array of ES.

The choices favoring nature’s management or conservation strategies are related to the benefits that different actors can draw and to external costs and benefits induced. They depend on perceptions of use and the services it furnishes. External costs can be not reflected in local incentives. The social value is to be set through political process leading to potential solutions. The question of choice then becomes that of the relative weight of different users in the decision. The choice issue can lead to ES supply gaps or loss of ES, when dealing with global demand vs local supply of ES, with in and off site users of an ecosystem, or with exploitation vs conservation strategy of an actor.

ES markets or compensation payment can be seen as one of the potential solution to involve positives incentives and articulate these scales of decision over bundles of ES. As it is difficult to measure many of the ES, payment for ecosystem services are based on actions of ES providers or indirect ecological indicators.

The intention of scholars is to develop a reasonably straightforward set of protocols identifying array of critical services. Studies about ES usually look only at few delivered services over a fairly bounded scale with little consideration over future dynamics. Further on, those approaches have problems facing the complexity of the relationship between biodiversity and ecosystem functions. The scientific challenges are then set ; there is often no good metrics are available for off-site unpriced ecosystem service flows (other than carbon sequestration eg.water quality, diseases), little understanding of the trade-offs between services affecting different constituencies, few data on their governance, and therefore no basis for evaluating options for accommodating interdependent off-site effects in local landscape management. The ecosystem services framework has four main consequences for target setting (Perrings, Naeem et al. 2010):

- “what and how much biodiversity should be targeted for conservation depends on what services are important to maintain and with what reliability;
- the temporal and spatial scale of targets should be based on the changing temporal and spatial distribution, and risk profiles, of ecosystem services;

- target development and implementation should include all agencies involved with management of biodiversity and the ecosystem services they support;
- interdependence among ecosystem services, the benefits they provide, and the value placed on those benefits implies that targets must be conditional".

This approach can be linked to the resilience approach, as acknowledging that adaptive flow of ES are granted by the resilience of the SES. If resilience decreases, the future flows of SE are also decreasing. But the B&ES approach challenge the idea of diversity as a response to human nature interactions problem. The choice of diversity options depends on the challenge faced.

SOCIAL REPRESENTATIONS AND MENTAL MODELS (T. LYNAM)

Social structure may be described as comprising the relationships of definite entities or groups to each other, enduring patterns of behavior by participants in a social system in relation to each other, and institutionalized norms or cognitive frameworks that structure the actions of actors in the social system. Social representations are "…systems of values, ideas and practices…"(Moscovici 1973) that are socially constructed (Thompson and Fine 1999; Semin and Smith 2002). The notable overlap in the definitions of social structure and social representations suggest that at least theoretically, social representations are an important component of social structure as well as underpinning social agency.

Modern theories of social change (Giddens 1984; Archer 1995) note the dualism between social structure and agency; social structure constraints or enables the actions of social actors and people modify social structure through their actions (agency). As important components of social structure, social representations and mental models constrain or enable human action and are modified by human action. They therefore provide an important body of theory from which to explore the SETER case studies. Theory is not clear on the differences or relative overlap in social representations and mental models (see for example (Breakwell 2001). Social representations are the common sense and hence socially shared representations of the world that have core (fundamental and slowly changing) and peripheral (more individual and changeable) elements. For the purpose of this exploration of SETER project cases mental models are taken to be the representations that individuals construct of the world about them at a given time, in a given setting for a given purpose. When people compile a mental model of some phenomenon they draw on their personal experiences, their beliefs, the social representations that they co-create and share and what Moscovici (Moscovici 1984) calls the reified or scientific information that may be available to them. Defined in this way (i.e. as being compiled from beliefs, social representations and available ancillary information in a given setting at a given time and for a given purpose) mental models are able to explain the troubling differences that have been observed in what people say they do relative to what they actually do (i.e. espoused theory versus theory in use, (Argyris and Schon. 1974); the action of undertaking a task versus the action of relating why a task was done have different purposes and are undertaken in different settings. We should expect therefore that the mental models of these different tasks may be substantially different.

Coordination is required for successful collective action; whether at the level of the small group (e.g. work team) or at a societal level (e.g. a food production and distribution system) the actions of individuals or groups need to be coordinated. For food to be on our tables each night requires the coordinated actions of producers, transporters, wholesalers, retailers and family members. Without

collective coordination little can be achieved. There are three major mechanisms through which we achieve coordination; markets; regulations; and beliefs or mental models. Whilst the role of the first two may be obvious an example may be needed to make concrete the third. Through the propagation and adoption of the beliefs associated with what Gandhi called "*Satyagraha*" the coordinated actions of people of India brought about huge changes in their political and economic situations (Shepard 2004). People believed in the goals and methods Gandhi proposed and acted in accordance with these (e.g. civil disobedience) and through so doing achieved their ends.

Beliefs clearly underpin both market and regulatory mechanisms for achieving coordinated collective action (for example people need to understand how trading happens in a market and need to understand the consequences of breaching a regulation). However, for the purpose of analyzing the SETER project cases, focus will be on the contribution of beliefs (i.e. social representations and mental models) to our understanding of the SETER project cases. Where mental models or social representations of market or regulations are identified they will be included but the focus will be on the mental models or social representations of these and not on how the market or regulatory instruments are constructed or function.

Mathevet (Mathevet, Etienne et al. 2011) have observed in previous work on mental models the evolution of the mental models of people interacting in a particular social setting towards a consensus set of beliefs as to the social actors, resource elements and processes in a natural resource system . They have also observed quite different representations being held by members of social groups that were in positions of conflict over a particular ecosystem (Stone-Jovicich, Lynam et al. 2011). The mental models of participants in given settings may thus have much in common (i.e. tend toward consensual) or have very little in common depending on the degree of shared positive action. Action is therefore a mechanism for building consensus as much as it is the result of consensus. How different social groups construe a given situation (i.e. their mental models of the situation) will strongly affect their responses to that situation. With different conceptions of a situation by different social groups the outcome of the situation is unlikely to be predictable with high reliability or certainty. In situations where consensual representations are highly inaccurate, predictability is also likely to be low however it may often be the case that we have no way of knowing what is an accurate or inaccurate representation. Where relatively accurate, consensual representations are present the predictability of the outcome may be the best (among these three situations).

It is tempting to take the relative power of the different groups in a particular situation as indicators of the weight of the representations of different groups in determining the outcome of situation. However, two observations suggest this weighting would be only partially useful; the first is the observation that the attributions of power we make are part of our mental models – by believing social groups have power, we give them power. Thus each actor in a social setting co-constructs the power relationships in that setting. The second observation extends the first; there are cases in which the perceived power at the start of the situation was not a good predictor of the outcome of the situation. The change in social attitudes to smoking in spite of the relative power of the economic forces supporting smoking is an example (Berger 1991) and the changes Mahatma Gandhi contributed to achieving in Indian politics and economic relations is another (Shepard 2004). Theory suggests caution in assuming we can predict

outcomes in complex situations (Kurtz and Snowden 2003). Sets of mental models of issues evolve as ongoing narratives which may take many forms (e.g. reports, papers, movies, news reports or stories). These narratives reflect the mental models of a specific social group in a particular setting or they may reflect the narratives of a part of a group in a particular setting. For example, an accurate news report based on an interview with a single member of a group may represent just that member's narrative or that of the group.

A number of elements of a group's representation of a situation will be used to focus the analysis of SETER project cases. Firstly how a group and how different groups name or label a situation is important; whether it is labeled as a problem or as an opportunity, or as a crisis or a concern the name or label provides an indication of the group's conception of and valence towards the situation. Secondly, how the different social groups that are represented in the mental models of a specific (reference) group as well as the naming or labeling of these groups may provide information on the reference group's construal of the actors in the situation as well as the reference group's relationships (including valence) to these actors. Thirdly, the referent group's naming or labeling of factors contributing to the situation or their naming of courses of action that they promote will tell us about the referent group's mental models of causality or action.

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APPENDIX 2. THE CASES STUDY INVOLVED IN SETER PROJECT

WETLANDS OF THE RHONE RIVER DELTA (CAMARGUE, SOUTHERN FRANCE)

The Camargue Biosphere Reserve lies in the Rhone river delta bordering the Mediterranean coast in south-eastern France. This deltaic system covers an area of about 145 000 ha and is characterized by a mosaic of fresh, brackish and saline wetlands interspersed with areas used by intensive agriculture or industries (Mathevet 2004). It is recognized as a wetland of international importance for the diversity of its ecosystems and the large numbers of breeding and wintering water birds (Heath and Evans 2000). Covering about 16% of the whole Camargue area, rice is the most widespread crop in the delta, either in rotation with wheat or in monoculture; the alternative crops being limited by soil salinity (Barbier and Mouret 1992). Earlier studies have highlighted the strong complementary roles of farmland and natural habitats for water birds (Pirot, Chessel et al. 1984; Hafner, Dugan et al. 1986). During the last 20 years, the management of these wetlands has been characterized by the building of embankments, the mechanical removal of vegetation, freshwater pumping, and control of water levels; all leading to a loss of biological diversity (Tamisier and Grillas 1994; Mathevet R. 2007). There is a need to reconcile wetland conservation with the development of an economic activity (wildfowling) whose financial contribution to local agriculture allows essential natural water bird habitats to be preserved. Moreover, while facing the global change and increased involvement of local stakeholders in regional planning, the managers of the Camargue Biosphere Reserve need to develop adaptive co-management strategies and methods to adjust land use and conservation policies to climate change, agricultural policy evolution, industrialization, urbanization, tourism development, and Rhone river flooding and sea level rising. For many years researchers have been examining how the local landscape has changed, and how changes in land use and water management practices have affected the population dynamics of bird species and conservation status of wetlands.

LOCUST CONTROL IN THE SAHELIAN REGION

Since the distant past, for many of the poorest countries of Africa, Desert Locust has been one of the most serious crop pest (Steedman 1990). People living in these countries have been seriously hampered by damage caused by this insect. This is a very ancient and regularly occurring phenomenon. The basic scientific locust control principles were first outlined by Boris Uvarov as early as 1937 during an international conference on natural disasters (Uvarov 1938). To mitigate the risk of crop losses, the requirements are a good understanding of the species' ecology in order to be able to locate outbreak source areas and carry out preventive control, and also an excellent international cooperation, which is essential due to the high migration potential of this locust.

Research efforts undertaken for a long time resulted in the setup of a preventive control strategy (FAO 1972; Hafraoui and McCulloch 1993). During the first half of the 20th century, there was a rapid increase in knowledge following Uvarov's discovery of the phase polymorphism phenomenon. During the 1930s, the main outbreak areas—which were still unknown—were sought. Then in the late 1930s, the outbreak source areas were generally outlined (for the desert locust and the other main locust species). From that time it was possible to develop a preventive strategy for controlling populations in

outbreak source areas. Preventive control organizations were created in various countries. Then, the ecological conditions that facilitate the transformation from the solitary phase to the gregarious phase were slowly better understood. As a result of all this research, invasions are now rare and brief. The control strategy implies monitoring ecological conditions and the locust in its outbreak areas, and conducting preventive treatments against the first gregarious locusts. Regularly applied and improved, this strategy made it possible to reduce the frequency and the duration of the invasions since the 1960s (Skaf, Popov et al. 1990 ; Lecoq 2001).

However, these invasions persist. The most recent one occurred in 2003-2005 and the previous one in 1987-98. Once more, although it was announced by the experts, it could not be stopped on time. Why? And why some plagues cannot be avoided? Of course, the problem can be solved, but only at the cost of heavy expenses, much energy, and the application of large quantities of pesticides in the environment, all of which could have been avoided. Could the problem be better controlled?

The latest plague indicates that it is now essential to radically change our way of thinking, perceiving and dealing with this problem, and to introduce new and innovative approaches to locust issues. Ecological research is no longer the key factor with respect to plague control. The current limiting factors are mainly organizational in nature. The recent plagues were the result of major malfunctions in the desert locust preventive control strategy, and it is clear that current problems in the management of this natural risk are mainly organizational. These organizational issues should be prioritized, otherwise research findings will be wasted. In other words, every time there has been an outbreak over the last 50 years, the main root cause of the problem involved the human organization, and rarely a lack of knowledge. This means that ecological research must be supplemented with research in alternative and less traditional fields.

Strengthening of national locust control units is still far from being sufficient. This is not the real solution to the problem. We must deal with flexibility, a key to the sustainability of the international control organization. For this, we need to consider the locust problem not solely in terms of crop protection, but as a natural hazard with many impacts: agricultural, economic, social, environmental, and political. To deal with this multidimensional problem, it is necessary to build an effective locust risk management plan, developed at different levels - international, regional and national - and include several warning levels, with a specific organization for each one, in order to stall crises before they worsen. This type of instrument could provide a suitable extent of flexibility and reaction potential. But it will only work if funding is readily available to deal with locust situations, and if the needs are clearly known in advance. This would require the creation of an international reserve fund and mobilize countries and donors on a long term basis (Lecoq 2001).

Focus should also be placed on another key point that was recently noticed: the numerous stakeholders involved in desert locust control. The rationales and strategies of these diverse stakeholders can differ markedly. They can be convergent or divergent, and enhance or hamper efficient locust control. A lack of recognition and understanding concerning the many different stakeholders involved in desert locust management - and their operational rationales - is a critical shortcoming. This is a major cause of the malfunctioning of locust management and is detrimental to control efficacy.

Nowadays, desert locust problems should clearly be seen as a risk management system for a natural disaster, still considering standard biological and ecological mechanisms as in the past, while also integrating studies on social, economic, organizational, and cultural mechanisms that were generally overlooked in the past. This is one of the keys to ensuring the sustainability of the locust management system. There is a need to turn towards a more anthropological approach to locust issues and consider them as a component of dynamic social-ecosystems, and thus to apply socio-ecological framework to the locust control policies.

MULTIPLE USES OF SAHELIAN ECOSYSTEMS AND RESILIENCE OF INSTITUTIONAL ARRANGEMENTS

Sahelian ecosystems are known for their intricate multiple uses of their resources: fuelwood (supplying 90% of the energy needs of urban and rural populations), farm and extensive grazing land, non-timber forest products for human and livestock consumption, habitat for biodiversity, carbon storage, etc. These ecosystems have been often described as man-made systems threatened by the exploitation of a rare and disperse forest resource, and by land encroachment through the conversion of forest into arable land (Fairhead and Leach 1998). But Sahelian ecosystems demonstrated their resilience following the severe droughts of the 70s. The continuous co-evolution of the biological (trees & grasslands) and social components (men & livestock) played a major role in buffering the effects of environmental variability (species adaptation to fire, weed dispersal by livestock, etc.).

A Malian case study is selected to illustrate the trends affecting the social-ecosystems of the Sahelian region of Africa. But in all the Sahelian countries, the post-drought period has seen the emergence of new institutional arrangements to reintroduce territorial organizations and controls on resource use through devolution policies (Agrawal and Ribot 1999; Gautier, Gazull et al. 2006).These socio-ecological systems need to cope with numerous constraints: limited productivity of natural ecosystems, increased urbanization leading to stronger relationships between urban needs and rural development, extensive agriculture with low physical productivity level, pressure on land availability, environmental variability, and limited rainfall.

Three types of emerging stakes highlight the necessary trade-off between the multiple uses and functions of these ecosystems:

- Land use stakes: competition for land to meet rural (agricultural and livestock productions) but also urban (food and energy) needs, leading to migrations and secure access to land issues;
- Biodiversity management and conservation stakes in a multiple use context, leading to land fragmentation and social exclusion issues;
- Global change and energy stakes questioning the medium term alternatives to fuel wood supply of Sahelian cities, and the sustainability of these SES local development patterns.

The management of Sahelian ecosystems has evolved since the 90s. Formerly, management practices focused on biological control of the ecosystem exploitation by relying on a centralized control of state forest and a lack of interest in extensive farming (extensive cropped areas being included in the forest domain). More recently, a shift toward more sector-based land-use policies was observed leading to institutional arrangements characterized by a lack of integration of agricultural concerns, ecosystems conservation issues, and livelihoods needs:

In extensive farming areas, the enforced fuelwood management policies illustrate the tension between the demand for energy of urban populations and institutional arrangements fostering the local management of the resource (Benjaminsen 1993). The implementation of devolution policies is hampered by power balance and information asymmetries between parties (local communities, communes, state administration, and traders). The effects of management norms and policy tools on the resource base, and on local development is still a concern . Mali experimented community-based natural resource management (CBNRM (Hulme and Murphree. 2001)) of biodiversity as an alternative to national protected areas designated for conservation. The analysis of how such local institutional arrangements are designed to manage biodiversity "should" allow discussing the frequent gap with the international stakes and principles underlined in the Convention of biological diversity.

In parallel with the policy shift, research undertaken on Sahelian savannah and forest areas first focused on the long term balance between fuelwood supply and demand, and its impact on forest degradation. The Cirad was involved in research supporting the implementation of new forest policies based on a more important involvement of local people in the resource management. Field works were conducted and data were collected on ecological productivity, on and implementation monitoring. Then research looked at the issue of land conversion to extensive agricultural production and the enhancement of agricultural production. Nowadays, a new paradigm is required to ensure a balance between biodiversity conservation and agricultural production, and to cope at the same time with poverty alleviation.

MANAGEMENT OF BEMISIA-PHYTOVIRUS RISK IN PROTECTED CROP IN MEDITERRANEAN ZONE.

In France, tomatoes produced for the fresh market are mainly grown in heated greenhouses with long cycle of continuous crop (11 months). The Rhône-Mediterranean basin produces more than 45% of French tomatoes. Before the year 2002 , 80 % of growers were controlling tomato pests using Integrated Pest Management based on biological control (IPM –BC), a strategy that uses fewer insecticides, because the durability of their production depends on quality. Quality of production and the tomato itself, is considered by the consumer as health factors. This orientation, in conformity to the European policy of pesticide reduction, is strongly supported by the Fresh Fruits and Vegetables Agency (http://www.aprifel.com). In spite of the negligible expense of the chemical protection of the cultures of tomatoes under greenhouses (2 - 4 % of the total cost), the reduction of pesticides is a priority objective.

In 2002-2003, growers were the powerless witnesses of a new phenomenon which devastated their crops. The culprit *Bemisia tabaci*, a small insect is considered to be a major pest on a worldwide scale. This cosmopolitan and polyphagous species has a very large range of host-plants and attacks ornamental as well as horticultural crops. Direct damage is important but the status of major pest is due to its action as a vector. *Bemisia* is able of transmitting more than 110 phyto-viruses among which some are very harmfull like for example the Tomato Yellow Leaf Curl virus (*TYLC*).

The sudden outbreaks of *B. tabaci* populations in greenhouse tomato productions in south of France in 2002-2003, associated with the *TYLC* the insect was carrying, generated a major phytosanitary (plant health) crisis . The presence on tomato of *Bemisia* infested by *TYLC* increased considerably the harmfullness of this whitefly, questioning progress accomplished these last twenty years in IPM-BC. The

impact of the *Bemisia-TYLCV* was so strong that it destabilized the whole commodity chain of greenhouse tomato production in the two main production basins (Languedoc-Roussillon and Provence Alpes-Côte d'Azur regions). *TYLC* problem was already known in others tomato producer countries like Spain, but it was new for France. Thus, the first reaction of French authorities was to classify the virus as agent of quarantine and to supplement European directive on the spread of viruses by orders of obligatory control of *TYLC*. In concrete terms, the presence of *TYLC* has to be declared to the Plant Protection Agency services (SRPV) and the whole crop has to be pulled up without financial compensation.

In a context of global change, the risk of Bemisia-TYLC became therefore a question of research and development with numerous scientific stakes and with important collective stakes for the socioeconomic actors as well as for French authorities. The combination between this type of phytosanitary crisis and the global change should lead to a sound analysis of the development schemes for the fruit and vegetable channel with final objectives of product quality and marking. The actual crisis gives the opportunity to constitute an interactive scientific community capable 1) to analyse all the technical and organizational aspects facing with the management of major phytosanitary risks dues to bioinvasions and 2) to anticipate and overcome global change impacts.

The context of this work is a phytosanitary crisis: the introduction/establishment in France of an insect of tropical origin, vector of very harmful phytoviruses for ornamental and horticultural crops associated to favourable geographic situation for bioinvasions. In 2002-2003, population outbreaks of the whitefly Bemisia tabaci on tomato in greenhouses of Roussillon and South-East basins associated with some spot of Tomato Yellow Leaf Curl (TYLC) disease have profoundly destabilized the entire production channel of tomato in France (Dalmon, Cailly et al. 2003). In the socio-economic context of Rhône-Méditerranée basin, fresh tomato production (45% of national production) is mostly based on large vegetative cycle with varieties TYLC sensitive. The use of whitefly proof nets was the first prophylactic measure adopted to decrease the introduction frequency of Bemisia adults without excluding the others means of control (Fargues, Bonato et al. 2004). Because temperatures of June and July generate ideal conditions for introduction, establishment and extension of Bemisia-TYLC spots, the increasing occurrences of such hot wave, like observed in 2003, should questioned in the next future the sustainability of tomato crop productions in greenhouses in the Rhône-Mediterranée basin and principally in the Roussillon.

A chance to tackle the adaptability of vegetable productions facing bioinvasion risks depending on global change. In a context of internationalization of markets, the organoleptic qualities as well as sanitary status of fruits and vegetables, the environmental quality of crops, and the marking of fresh products, are nowadays considered as corner stone for developing such agricultural activities. This postulate is based on the considerations made by the professionals (ONIFLHOR) and incitation by customers around the theme "fresh product = health factor". At European level, policies are going the same way restricting very strongly the use of chemicals. Because of progress during the last 20 years in terms of Biological and Integrated Protection, especially on tomato crop, this objective seemed reachable (Van Lanteren 2000). But the introduction of whiteflies infested with viruses has "de facto" generated a phytosanitary crisis questioning all the knowledge by considerably lower the damage thresholds (Fargues, Bonato et al. 2004).

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APPENDIX 3 DIFFERENT CASE STUDIES THROUGH THE DIFFERENT LENSES

The appendix 3 was assembled by F. Bousquet through notes taken during invited researchers final presentations. The objective is to be as close as possible from the presentations, but the text is under the responsibility of F.Bousquet.

DESERT LOCUST MANAGEMENT

LOCUST AND VULNERABILITY

The overarching research question is: What explains the vulnerabilities of herder groups associated with the one or more stresses (Development of swarms; socio-economic instability; climate change) threatening the socio-ecological system? Concretely, the herder groups selected for the study would be, for 2003-05, 10 Mauritanian herder groups, chosen because they (a) occupy the outbreak zone, & (b) represent variation on a measure that may influence vulnerability (e.g., average age of the group).The study would be done with the exposure-sensitivity-adaptive capacity frame.

The exposure is the description of the intersection of the hazard with the exposure unit. What was the climate during/preceding this period? What was the vegetation during/preceding this period? What was the livestock type/composition in the herder groups prior to the swarm?

The sensitivity is the short-term impacts/responses & conditions mediating the production of the impacts following the exposure. How fast was the solitary / gregarious transition? How was the vegetation managed before the swarm? Were the herder groups, prior to the swarm high/low social status? numerous/small? old/young? What was the socio-political stability of the country prior to the swarm? Were areas of instability co-incident with the herder group traditional areas, the migration traditional areas? How many livestock/people were lost/killed? Injured? What short-term responses (eg, migrations) did herders implement? Were there social conflicts following the swarm? What short-term responses (eg, insecticide spraying, financial compensation, food aid) were implemented by responsible institutions (eg, FAO, “equipe de reponse rapide”)?

The adaptive capacity is current/future abilities & inabilities to implement effective, long-term responses, determined in part by an understanding of previous impacts/responses. After the swarm ended, did the vegetation re-emerge? If so, after how long? How extensive/heterogeneous/dense was the vegetation after the swarm? What long-term social assistance programs were provided by the government or another collective action institution (eg, FAO)? Were these macro-level social assistance programs effective? What long-term responses did herders implement, wish to implement but could not implement, were these individual-level long-term responses effective?

LOCUST AND RESILIENCE

Cascading biological phenomena such as the desert locust outbreaks can be described as alternating phases or states of a system (Ludwig, Walker et al. 1997). One phase is the low population density (characterized by the solitary insect type). Food and water resources, and perhaps predators, would all act to limit the population size. Pulses of rainfall would increase the food base, and temperature increases would spur regeneration times, triggering a transition to the other state. This alternative phase is one where the gregarious type locust is dominant, and rapidly spreads across space and time, with little or no control. Once the energy sources fueling the population increase are used, the erupting population collapses back to the low-density phase. While struggling to be functional, the FAO plan for desert locust control is an example of an alternating social regime, where the institutional focus shifts from monitoring during dormant phases to pesticide control during locust outbreaks.

The ecological dynamics can be viewed in terms of cross scale phenomena, or as types of panarchies (Gunderson and Holling 2001). The spreading insect outbreaks cascade upscale, and are consistent with revolts as described by panarchy theory. In revolts, the variables that control the populations at small scales are no longer functional, and in the case of the desert locust, the insect literally becomes a different animal. The connectivity of food and resources across the landscape is such that the locust can quickly spread and consume those resources. The revolt continues until resources are consumed and the energy supporting the revolt collapses.

The questions to be addressed are:

- What are competing models that explain long term cycles of outbreaks?
- What are alternative institutional settings for managing outbreaks?
- What are the links between traditional knowledge and modern monitoring?
- What is the functional role of locusts in system? Do they recycle nutrients?
- How have land uses altered resilience?
- Have grazing, farming enhanced outbreaks?
- What are the long term effects of pesticides?

The following steps would be to start a modeling of the outbreaks (10-15 year cycle), to undertake a comparative institutional assessment between international centers for disease control and US interagency fire fighting and to develop a proposal for a study on the interaction between land use and resilience.

LOCUST & POLITICAL ECOLOGY

In general terms, for political ecology several aspects should be considered. The problem is rooted in the spatial/territorial mismatch of political territories and locust breeding sites (micro) and invasion paths (international). The significant impacts match with massively mobilized capital resources. There are diverse and divergent interests in control and impact. Politics of knowledge should be analyzed, the development and legitimization of expertise and expert power and the “vacuum” of local knowledge. Finally the problematization of locusts’ management should be situated in colonial history and transformation of governance in the modern era.

These directions of research would contribute to different general debates.

Globalization exacerbating international problems: trans-boundary problems unsolved by trans-boundary organizations. This general issue is here linked to the ecological process: what type of dispersed governance should be organized for dispersed ecologies? How states respond and evolve when facing new ecological challenges? Where does development capital from locusts accumulate?

Several themes were identified

Theme 1: Herders & Agencies. The problem can be defined as a problem of distribution of herders across landscape in areas of locust outbreaks, while the information and coordination with these communities is poor. Thus, theoretically, the problem is a problem of confrontation between local ecological knowledge (*metis*) and state knowledge (*techne*). The goal of the study according to this theme would be to understand local actors, perspectives and narratives working along Scott[2] and others line on proximity of experience of local people and its conditioning and assembling network of knowledge amongst diverse public.

Theme 2: Situating the locust, an historical political ecology. What happened during previous management regimes and what were the socio-ecological effects? The previous ordering of the locust problem and relationships between local people and varying institutions are not the same as the ones that exist now. Yet we know little about how problems were dealt with in previous periods, how locusts and people were governed. The study would have two key goals: can we learn from the past to cope in the present? How did present dysfunctions come to be and how might they be undone? Theoretically this work is framed by the idea that colonialism and capitalism transformed the "crisis" owing to the larger political economy (Watts and Bohle 1993; Peluso and Watts 2001) and the fact that modern expert power has come to crystallize in the institutional relations of the present (Mitchell 2002).

Theme 3 Geopolitics of Insects. What geopolitical and agro-economic conditions prefigure cooperation or cooperative failure? To what degree does locust cooperation generate new openings for cooperation? These questions comes from the observation that Morocco (wealthy invasion state with agriculture) donates to Mauritania (poor outbreak state) but Saudi Arabia (wealthy outbreak state without agriculture) does not donate to Yemen (poor invasion state with agriculture) and Morocco and Mauritania are NOT historically friendly, but this provides an entry point for relations

Theme 4: Cycles of Remembering and Forgetting. Momentum and resources are mobilized during outbreaks and invasions, but knowledge goes into remission. The hypothesis is that invasion areas remember & outbreak areas forget. The theoretical framing lies in Douglas work (Douglas 1986).

Theme 5: Cycles of Resource Generation and Dissipation. While locusts go through a cycle of outbreak and invasion, the international community goes through a cycle of motivation and oblivion. The donor

[2] James Scott's work focuses on the ways that subaltern people resist dominance. His original interest was in peasants in the Kedah state of Malaysia, and he wrote *The Moral Economy of the Peasant: Subsistence and Rebellion in Southeast Asia* (1976) about the ways peasant people resisted authority. In Weapons of the Weak: Everyday Forms of Peasant Resistance (1985) he expanded his theories to peasants in other parts of the world, and in *Domination and the Arts of Resistance: The Hidden Transcript of Subordinate Groups* (1990) he argued that all subordinate groups resist in ways similar to peasants.

and receiver countries and institutions go through a cycle of “resource generation” and “dissipation”. The hypothesis is that crisis generates conditions for “remembering” locusts that are mediated by increasingly available capital and institutional conduits. The method would be to follow the money (Klinenberg 2002) with a careful accounting of when funds flowed, what was bought, and where did the materiel go.

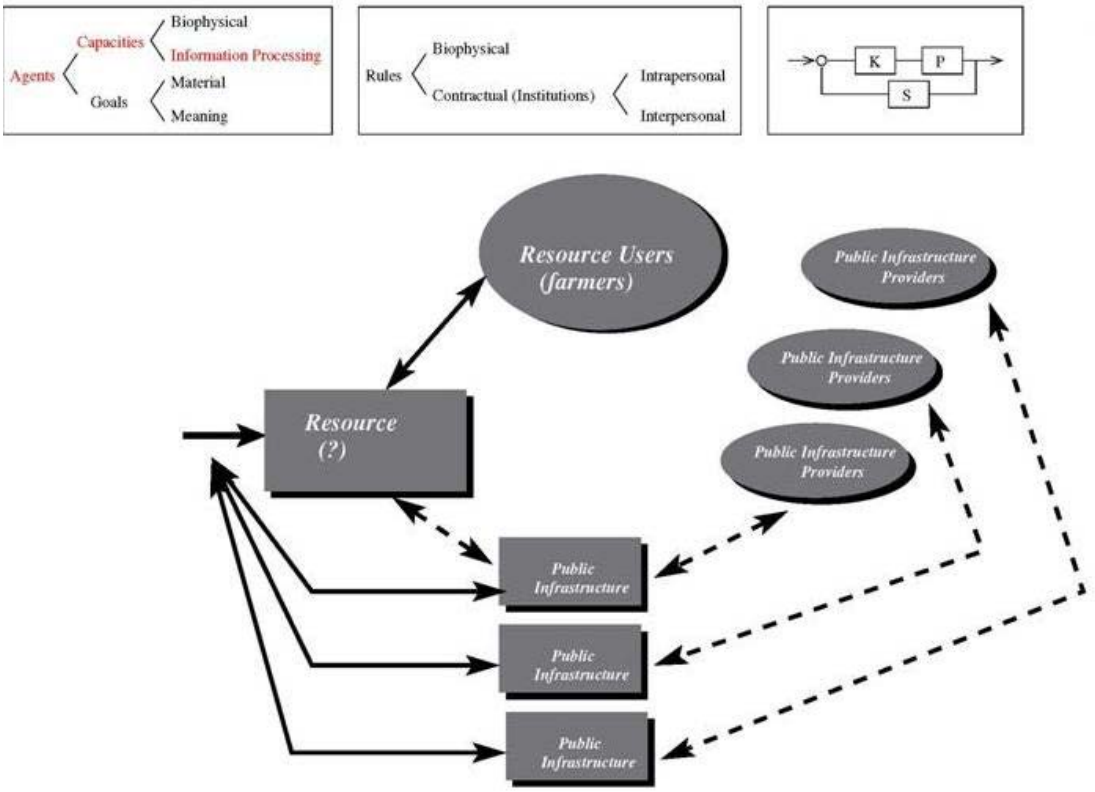
LOCUST, COMMON-POOL RESOURCES AND COMPLEXITY

Why is the control of desert locust too little too late, even though scientists can now provide accurate warnings ahead of time? Some reasons are the “disturbances” (Rainfall events, Insecurity/conflict areas, the perverse incentives to report bands (no co-production), the delays of FAO report, the rapid turnover in decision makers. An important point is the institutional memory. What is causing the delay and loss of institutional memory? There is possibly a perverse effect if policy is effective, leading to a loss of memory and motivation. There is a scale effect: local outbreaks are tackled by national centers. It is at regional level that we observe slow response.

The problem is framed as a public good provision problem at international scale with important asymmetries of costs and benefits. An empirical analysis of incentive structure of different stakeholders of the social-ecological system is proposed. This is linked to the question on who benefits (Locust research, National governments and control centers, Pest control industry) and who loses (Unorganized farmers). The locust problem is a transboundary problem, with asymmetry of costs and benefits. The occurrence is uncertain and is dependent on changes of the environment. A model could be developed. It would be a spatial explicit model with locust bands, rainfall events, and different levels of local control. Countries would be “human agents” controlling desert locust. The question would be: what would be long term evolving strategies of agents to different types of institutional arrangements and ecological dynamics?

In terms of research on management, one could use role games to train decision makers at local and national level.

LOCUST & ROBUSTNESS



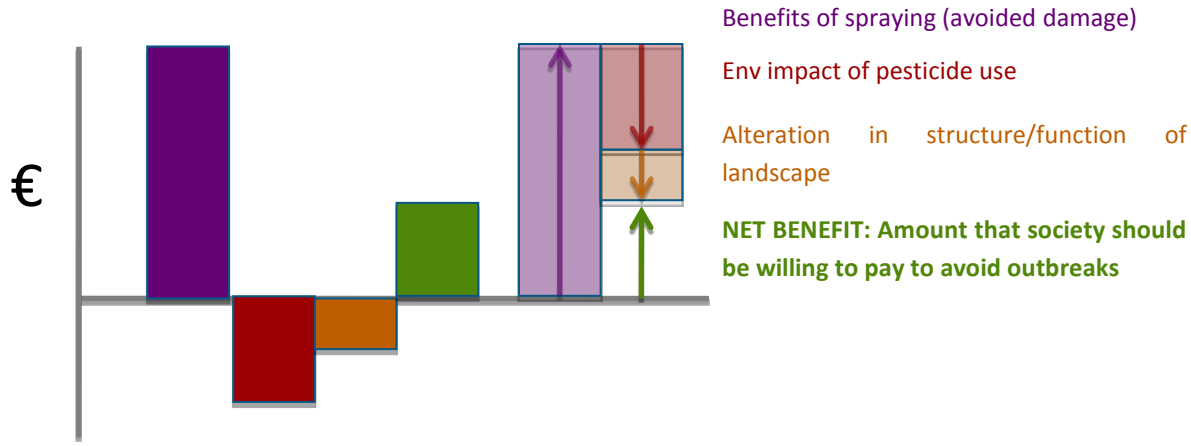
The above figure is a synthesis of the analysis. We see in red in the top boxes that the main capacity is the capacity of information processing. This case study is more based on agents and information's because there are not so many rules involved. In this case the Plant (P) is huge and the sensor (S) is very complex. Multiple actors are playing with many public infrastructures which in turn all act on the perturbation on the resource (locust population) rather than the resource. There are no connections between public infrastructure and resource users.

From this analysis comes a discussion on the fact that indeed resource users and public infrastructures are not connected. Putting resource users away leads to a lack of trust, thus no information is delivered to the public infrastructure providers and finally no possible feedback. In robustness sense, there is no signal then no feedback. The second discussion was on the institutional time lag. The problem here is the bandwith: it takes a lot of time to adapt.

LOCUST & ECOSYSTEM SERVICES[3]

It would be useful to have a wider systems perspective more generally. What are the (system-level) costs and benefits of controlling locusts? The figure below show the type of economic analysis that could be done.

[3] Reminder : C.Perrings and A. Kinzig had a very short time studying this case study



Locust outbreaks have been a part of this system for thousands of years. Are there other organisms that benefit from, or are *dependent on*, locust outbreaks (Birds, early successional vegetation) ? What cultural strategies arose around locust outbreaks, and how will those be disrupted by control? (Trade relationships, subsistence strategies)

LOCUST & MENTAL MODELS

The problem is technically solvable. The problem is social and political. This case is called healthy problem because there are no incentive for anybody to solve the problem. The assumption is also that the ecosystem might need the presence of the locust.

The questions would be:

- What are the operant MM? What the MM determining the outcomes of the system?
- Are there parallel coupled representations? There is a formal narrative of a crisis (FAO starts saying that there is a problem, governments will say it also). The formal narrative exists because there are less expressed mental models which are for instance the need of money. Are the formal and hidden narratives coupled and are they together maintaining the system?

Methods are about settings (are we in an outbreak or remission phase? In the site of far from the site?), time and groups (which groups?). Firstly, different themes would be identified through the use of different methods: documents analysis, media analysis and word association. Secondly, a setting (a story) would be created and people would be asked to react in this setting (for instance you are with people and you have to explain what's going on with the locust). People would have to write a story, which would be the narrative. Then analyze the texts would be analyzed with software to see the correspondences with the different themes.

The contribution would be:

1. For the case study: to try to identify the representations that maintain the system.
2. For theory: the relationship between settings (we would create different settings "it's been years since outbreaks" or "we are within an outbreak) and representation and action.

3. For action: if we accept that everybody wants to maintain, it is a healthy drama. Could we make an even healthier drama? For instance improve the problem of the insecticides.

BEMISIA

BEMISIA &COMMON-POOL RESOURCES AND COMPLEXITY

If bemisia case study is an example of possible invasive species due to climate change, we need to understand the lack of effective response at different levels of scale. What are the adapting capacities of the farmers? Farmers surviving in current high competitive market are likely to have common type of risk perception and social orientation. The suggestion is to perform survey analysis (including decision experiments) on risk attitudes and trust. The hypothesis is that the farmers are highly risk seeking, low trust in other producers and "government". The producers are able to move from one high gain high risk production system to another, especially by harvesting subsidies. The agricultural systems have evolved to go through overshoot and collapse cycles. The question is: what institutional incentives lead to this type of 'agents'?

Through this approach, two main questions are addressed:

- How to eradicate the threat of bemisia virus?
- Why is the capacity of agricultural industry so low to deal with invasive species?

The proposed method is to study spatial ecology of Bemisia building a spatial explicit simulation model at farm level to access policies and diffusion of virus among farms. This would define a model structure for future outbreaks. A series of basic information need to be collected:

- Why did farmers not get compensation? Who decided?
- What happened in other cases of invasive species?
- What are official policies on invasive species?

There are two stability domains:

- Producers who have labor intensive (subsidized) production of organic food of many different types: lower production, but more resilient.
- Producers who have capital intensive production of monocultures: high gains, but reasonable probability of collapse. This is typically effective to get governmental support to continue.

An evolutionary model could be produced, with producers with different attributes under institutional arrangements (subsidies, regulations). The hypothesis is that long-term focus on subsidy (money and research) leads to certain type of producers who are well adapted to institutional arrangements, but food production system is less reliable and more costly.

Experiments could be done. Given insights in attributes of producers, what are incentive structures to lead them practice preventive actions? The experimental problem (high gain, low probability of big negative effects) would test different incentives structures, for example conditional subsidies. (Example: Climate change experiments on policies and risk. http://www.cred.columbia.edu/)

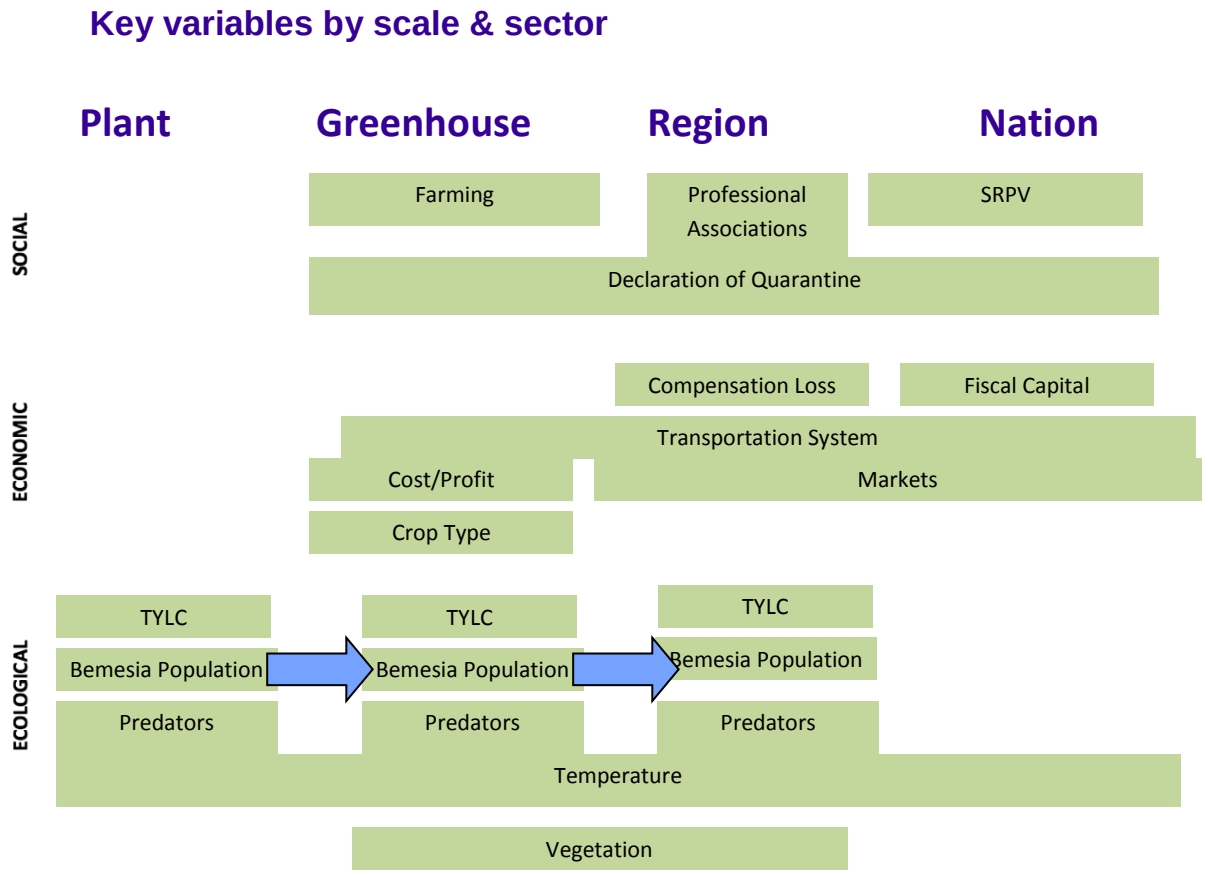
In conclusion, Bemisia is a great example to study a number of fundamental questions on the challenges of the current agricultural system with invasive species. The focus is on producers and how they game the institutional incentives.

BEMISIA AND RESILIENCE

The theoretical framework of resilience focuses attention on the system's key variables, by scale and sector and how these factors interact and generate shifts between TYLC outbreaks and senescence. It also attempts to understand how alternative policies could be formulated and tried to minimize disease outbreaks. There are known management strategies for dealing with TYLC in other places e.g., in Israel TYLC tolerant varieties are grown and taller greenhouses let the heat escape. However, in France the preferred response is to suppress *Bemisia* populations using chemical pesticides.

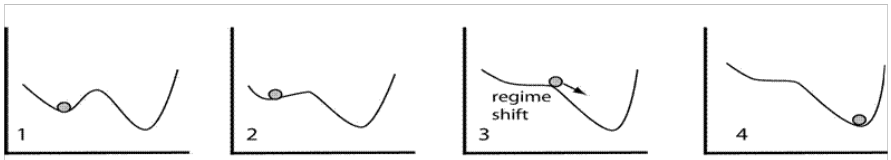
Consideration of the issue in the context of a social-ecological system helps to reveal key components of the social and ecological subsystems as a first step toward understanding system dynamics. The key components of the system are:

- Tomato Production
    - Tomato Cultivars
    - Greenhouse
        - Construction
        - Fuel, Labor
    - Markets
    - Growers and Professional Associations
- White Fly Population Dynamics
    - Nutrition/food
    - Spatial Refugia
    - Predators
    - Biotypes
- TYLC
    - Biotypes
    - Models of outbreak
    - Monitoring
    - Response to Outbreak
        - Declaration of quarantine status



In particular we look to see how the key factors interact across levels from plants to greenhouse, region, and nation. Top-down interactions include: crop compensation, control policy, and technology/energy. Bottom up interactions include: TYLC outbreak and tomato production. Applying the panarchy model one would see the top down (memory) composed of Crop compensation, Control Policy, Technology/Energy while the revolt from the bottom up would be Tylc Outbreak, tomato production decrease. Highlights from the case study description reveal panarchies or cross-scale interactions that occur at different phases as the system shifts from one of low TYLC levels to an outbreak regime.Examples of transitions from a regime to another would be:

Regime A	Alteration	Trigger	Regime B
No/Few TYLC	Vector-Bemesia Hosts-Vegetation	Temperature	TYLC Outbreak
No Compensation	Political power of associations	Quarantine Declaration	Compensation



Research questions that follow from considering panarchies and regime shifts in the tomato-*Bemisia* outbreak system might include: a) what can be learned about the regional spread of TYLC from greenhouse to greenhouse, b) what are the mechanisms of predator control, c) how might the problem evolve under changing and uncertain conditions (e.g., climate change), and d) what can be learned from the outbreak crisis, specifically with respect to the role of compensation as subsidizing pathology or forcing adaptation. More theoretical questions would relate to managing for specific vs. general resilience (i.e., specific resilience of tomato production system to TYLC vs. general resilience of greenhouse food production to future pest outbreaks and other unforeseen events). Finally, what can be learned from the case study about tradeoffs in managing systems at the edge of stability domains?

Using the resilience framework agricultural systems are presented as being the result of a trade-off between efficiency and resilience. Agricultural systems target the efficiency and pay the price in terms of resilience.

The final questions are

- Which are the epistemic communities? What are their particular roles?
- Does compensation subsidize pathology or force adaptation?
- What can be learned from interdisciplinary failures?

Next steps applying resilience framework are: development of food base, predator and regional scale spread models in addition to biophysically based population models. These would be developed as tools to integrate understanding of complex dynamics and develop possibly new ways of intervention.

BEMISIA & VULNERABILITY

The overarching research question is: what explains the vulnerabilities of the regional tomato production system associated with the climate variability/change (frequency/magnitude of canicules/secheresses); TYLC virus; tomato competition (Bretagne, North Africa, Spain)?

The study would be done with the exposure-sensitivity-adaptive capacity frame.

The exposure is the description of the intersection of the hazard with the exposure unit. What is the climate, especially the occurrence of droughts? How many tomato producers are in the region, what is their production capacity, and where are they located, Where has the fly been found to date? Is the virus everywhere the fly has been found to date? What is the current level of market share by producers from other regions (e.g., Bretagne, North Africa, Spain)? How has tomato production from these other regions for export to L-R recently changed?

The sensitivity is the short-term impacts/responses & conditions mediating the production of the impacts following the exposure. How much did tomato production/profits decline for regional producers in 2003? Which producers stopped growing tomatoes after 2003? What is the variation of bemisia population relative to temperature in the field? Do regional tomato producers use a greenhouse? produce other products? anticipate more the decrease of tomato production? use pesticides to target bemisia? pledge to be "bio" report the decrease of tomato production – or TYLC – to the CPA? Are answers to the questions above influenced by: the production practices elsewhere (e.g., Bretagne, North Africa, Spain)? French consumer preferences? participation in local "collective action" institutions?

The adaptive capacity is current/future abilities & inabilities to implement effective, long-term responses, determined in part by an understanding of previous impacts/responses. What do the farmers who grew tomatoes in 2003 produce today? What is the status of L-R "collective action" institutions related to tomato production? What is the function of these institutions? Where these institutions and what are their geographic mandates? What proportion of local production do these institutions represent? Are these institutions well-attended and/or well-financed? Have these institutions actually helped a significant number of individual tomato farmers in recent times of "crisis"? What is the prospect for developing additional collective action institutions in L-R? Can collective action – whether based on new or existing institutions - modify: tomato production practices in Spain or North Africa? French consumer preferences and liability? Is state compensation theoretically possible? difficult to acquire? significant once acquired? Are there disincentives to applying for state compensation, and if so, do these disincentives result in farmers not reporting the presence of the fly?

BEMISIA & POLITICAL ECOLOGY: THE NEOLIBERAL PRODUCTION OF RISK AND UNCERTAIN KNOWLEDGE

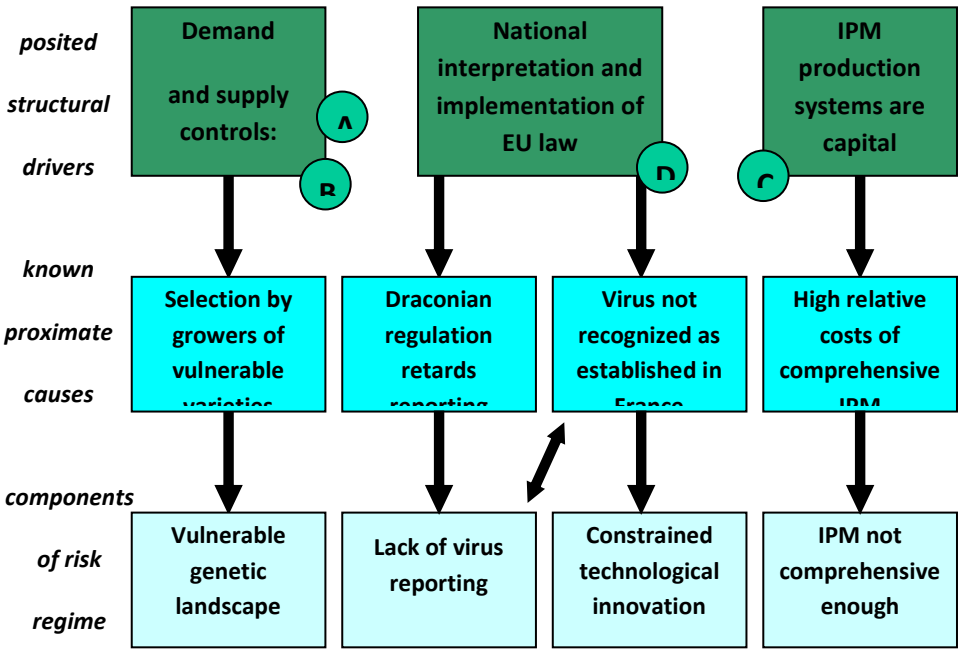
The key theme is the neo-liberalization of Agriculture as:

1) an ideological commitment to the reduction in state power relative to markets
2) a shift of risk and responsibility to individuals (Beck calls individuation (Beck 1992)), simultaneous with a change in regulatory regimes to favor trade
3) shifting accumulation regimes, typically to concentrated and large firms and to "off-shore" production sites, with cheaper labor markets and more relaxed environmental regulations

The conceptual model is a model of « risk regime ». The current risk regime is poised for an undesirable major outbreak following a heat wave or other stochastic event. That regime is perpetuated by a few specific conditions

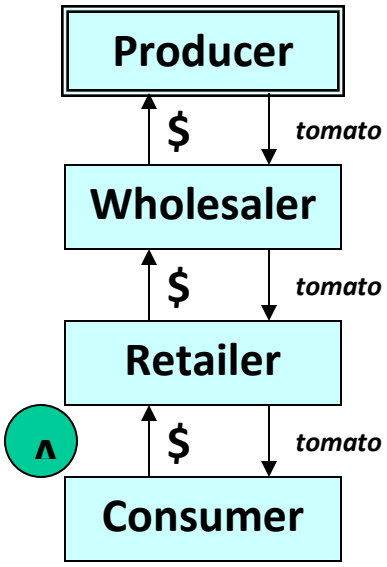
1. Vulnerable genetic landscape (monoculture/variety)
2. Lack of virus reporting and overall disconnection of producers from the regulatory and management regime
3. Constrained technological innovation in extension and science surrounding the virus itself
4. Absence of a multi-predator, comprehensive IPM amongst producers that might be robust enough to reduce outbreak

The risk regime persists because there is accumulation somewhere in the system. Where are the interests and how are they interested? The theoretical basis which lead to hypotheses is the agro-political economy (Kloppenburg 1988; Corburn 2005). The risk regime is locked into place by interests that benefit from, and are rewarded by, the current pattern of accumulation and management. The value accumulates along the current commodity chain. The regulation tends to follow interests so…follow the money.



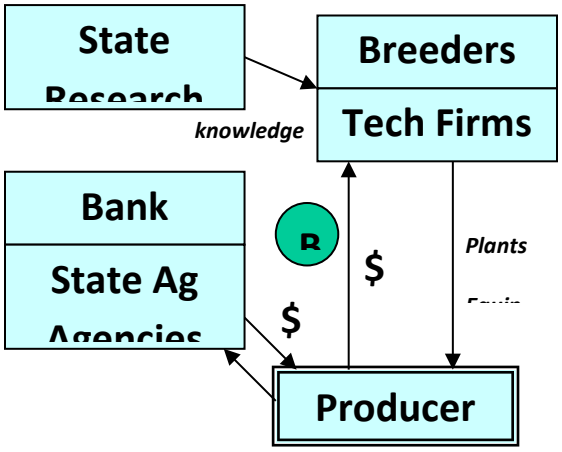
From the posited structural drivers 4 researches could be developed:

A The chain from producer to consumer : Concerning the variety selection: who makes money selling these particular tomatoes?



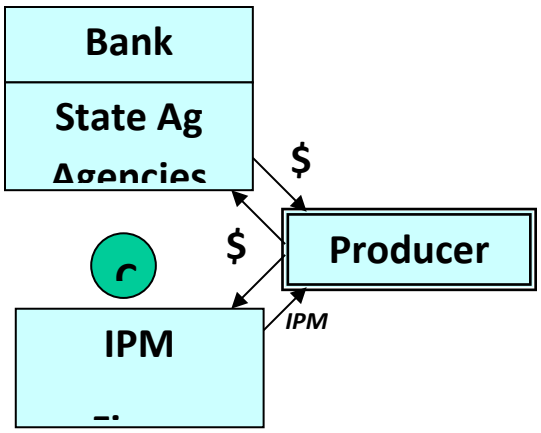
What criteria do supermarkets use in selecting varieties? How do marketers shape consumer preferences? What were the economic and political imperatives leading to the creation of the Rougeline label and how have these influenced the choice of variety?

B The technology chain How is the greenhouse/breed technology selected and who makes money?



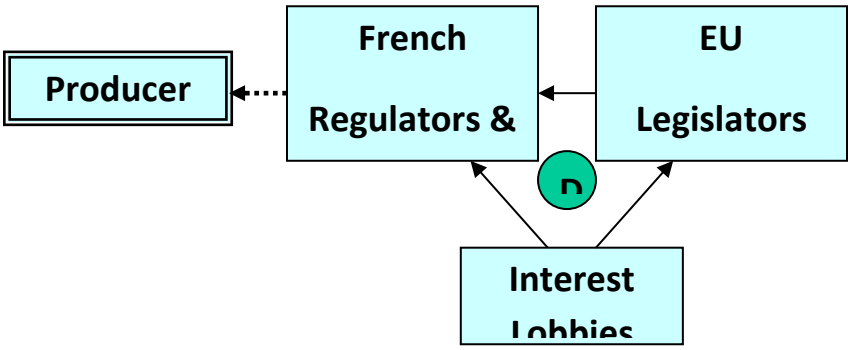
Where are the funds (loans, subsidies, reinvested capital) coming from to pay for investments in new technology? How have greenhouse technology and the tomato variety co-evolved? Who are the breeders and what is the relationship between breeders and greenhouse development providers? How are the relationships between state science and private breeders and greenhouse designers changing?

C. The political economy of commodity chain How has the political economy of IPM influenced the farmers ability to use it?



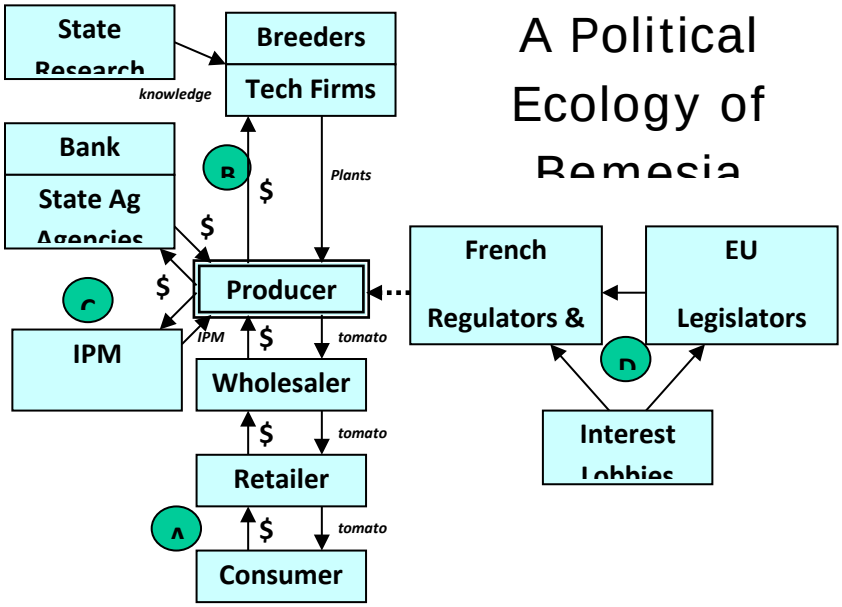
How and when was IPM privatized? How are intellectual property rights in IPM configured and adjudicated? To what degree do IPM firms depend on public research? What is the history of the relationship between IPM companies, state institutions and chemical pesticide producers?

D The regulation How have regulations and their implementation influenced the spread of Bemisia?



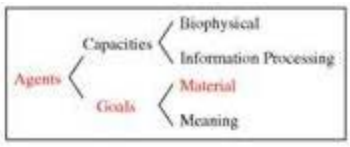
What is the history of the establishment of the EU law? (actors, timing, interests, justification) How were the French regulations written and with what interpretations of EU law? What causes under-enforcement of French regulations?

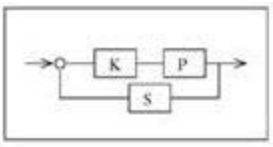
E. The whole chain

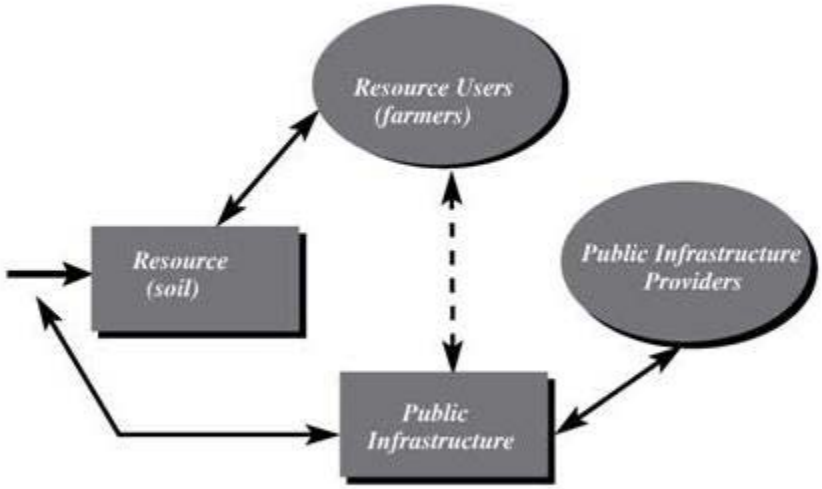


A Political Ecology of Bemesia

BEMISIA & ROBUSTNESS







In this case the resource users are the farmers and the external shock on the resource is the TYLC virus. The public infrastructure is composed of the rules, especially the withdrawal of the infected plants and the no-compensation rule. The interaction between the resource user and the public infrastructure is the sanction and it is very weak. In that case institutions sets up a very difficult intrapersonnal dilemma for the farmer: should I pull the plant? The farmer cannot decide well. Public infrastructure providers are not connected to resource users: there is no trust, no discussion among them. The consequence of this absence of trust if the fact that farmers suppress information, consequently there is no more sensor, no more feedback and this system cannot be controlled. It becomes very fragile. In terms of management the point is: given the signal how do we build the control to avoid oversimplification? Compensation could be seen as an overamplification, because the incentive of the farmers might be to declare even more to get more compensation.

BEMISIA & ECOSYSTEM SERVICES[4]

The overarching questions would be :

- How would possible policies for restructuring tomato production alter ecosystem services?
  - Field production versus greenhouse production
  - What ecosystem services does field production of tomatoes enhance? Degrade?
  - When production is moved to the greenhouse, what replaces field production? What are the ecosystem services (disservices) delivered by those systems?
- Is it productive to move beyond a question of how to manage Bemesia to an assessment of invasive-species risk more generally? Can "the next Bemesia" be anticipated?
  - France as both a *source* and a *sink* for invasive species.
  - Analysis of the likely sources of invasive species for France
    - By trade patterns
    - By proximity and biogeographic similarity of trade partners

BEMISIA & MENTAL MODELS

The overarching question is the adaptive problem solver. The scientist gives the impression that for science it is a failure but at the end the problem it is solved. There is here a pattern: producers declare the problem, technicians suggest and do experiments and scientist name the problem. Is this an adaptive problem solver?

The second question is on building the positive. Lots of the issues are issues of trust or faith. Producers do not necessarily trust, representations of others are constraints of trust.

Methodologically the investigation would be on how some groups think about other groups. Process would be through interviews on the perceptions of each other. "Can you list all attributes of the other?"

The contribution

[4] Reminder : C.Perrings and A. Kinzig had a very short time studying this case study

- For the case, would be to name a solution. Naming the adaptive problem solver, it becomes legitimate
- For the theory, each has a representation of the other. The theoretical hypothesis is that the worse the representation, the less trust.
- For the action: the relabeling. After relabeling each of the groups get better trust because they understand better the system they are part of.

SAHELIAN ECOSYSTEMS MULTI-USES

SAHELIAN ECOSYSTEMS MULTI-USES, COMMON-POOL RESOURCES AND COMPLEXITY

The broad topics are the problem of policy impact and adaptation of the stakeholders.

The first research step would be to combine remote sensing and field work to assess land use and land cover changes: are there differences between regions (with and without use of quota)? Who are the actors? This leads to an analysis at the regional/local level. What is the role of the black market? What are the flows of wood via own village (legal/illegal) and other villages (illegal)? Why are some people member of wood cutter organization and others not? Why do authorities not enforce regulations? (Forgone tax money, dubious spending?) Who is responsible and accountable and why don't they take the responsibility? What causes differences between Mali and Nigeria? How is the World bank evaluating the policy changes? What is reported? (Policies are successful since less than quota are harvested?)

The second research step would be on rules on paper and rules in use. The hypothesis is that if official rules for wood cutters would be strictly enforced this will lead to more deforestation. Official rules with group quota are expected to lead to rush for resources. Why is this not happening? And what are the rules the wood cutters use in practice? Experiments with and without strict enforcement could be done. The problem of strict enforcement by bureaucrats from city is an economic game. Experiments could be done on decision dilemmas to see how people perceive harvesting problem. Do they perceive it as a moral dilemma?

How are different actors able to adapt and postpone the crisis? The supply adaptation leads to postponing of the problem. What if the crisis occurs? Energy crisis will happen some day. How can we derive a smoother transition? And to what? Two approaches can be used:

- Survey: what are the important problems for their children, visions, solutions?
- Scenario analysis: bring together stakeholders and do a scenario exercise: What are alternative energy sources: oil exploitation? What if carbon sequestration market will play a role? Goal of the analysis is to engage the creativity of the local stakeholders in visions for future and possible solutions.

SAHELIAN ECOSYSTEMS MULTI-USES & RESILIENCE

The key components of the socio-ecological system are the decentralization of forest governance and establishment of rural wood markets, the spatial heterogeneity of wood resources, the access to and availability of wood, the institutions and rules for managing wood fuel resources, the adaptations to these rules and institutions, the social networks and stakeholder interactions, the long term tree regeneration rates, the economic opportunities at rural village level. At the landscape scale, Gautier and

colleagues (Gautier, Bazile et al. 2006) described how tree density, biomass and diversity vary with land use and can create different ecosystem states or phases. One state is the savanna state, another the agroforestry parklands, and another is a fallow state. Each of these types can transition into the other and each can provide different types of ecosystem goods and services.

This case involves a change in the social regime of how forest resources are used. Prior to 1990, the government controlled the open areas in Mali and harvesting of trees was heavily regulated by a Forest agency who granted permits to cut lumber. Following a shift in government, control of forest resources was ceded back to local levels through a scheme to create markets for fuel wood (Hautdidier and Gautier 2005). Backed by the World Bank, the new forest management regime was brought about by the creation of rural markets, local directors who would oversee cutting and a taxation policy to favor sustainable harvesting methods (op cit). However in this case there is no evidence that the change in policy led to different ecological states. The policy has changed, the rules and some connections between actors have changed, thus the socio-ecological regime was transformed but there was no ecological shift.

Applying the panarchy model one would see the top down (memory) in the fact that the desertification crises led to market approach while the revolt from the bottom up would be linked to the wood harvest patterns

The research questions would be:

- How can we better understand the relationship between wood fuel management and the spatial pattern of wood resources on the landscape?
- What are potential thresholds in the wood fuel market?
- What is the effect of tree regeneration rates on different forest types?
- What is the potential influence of large-scale regional vegetation shifts on climate?

SAHELIAN ECOSYSTEMS MULTI-USES & VULNERABILITY

The overarching question is: what explains the vulnerabilities of the system of villages–forests surrounding Bamako supplying the city with wood-energy, associated with the one or more stresses (**"**WB" policies on decentralization, management transfer, political stability, urbanization, climate change) threatening the socio-ecological system?

The study would be done with the exposure-sensitivity-adaptive capacity frame.

Exposure: prior to the WB policies, which villages were in the Bamako zone of influence? Which of these villages cut heating wood, and received the profits? What was the political situation in the city and its environs? In the country? What was the status of the forests (extent, locations, age, species)? What was the climate (drought) situation?

Sensitivity is the short-term impacts/responses & conditions mediating the production of the impacts following the exposure. Which villages were officially selected to participate in the management transfer program? Which selected villages showed quick significant new wood-cutting and what is the variation of profits in these villages? What intra-family changes were observed in these villages? Which non-selected villages showed quick significant new wood-cutting? What is the variation of profits in these

villages? What intra-family changes were observed in these villages? Is a greater volume of wood being cut today than prior to the WB policies? What proportion of the wood being cut today is transformed to charcoal? Prior to the WB policies, was the transport system connecting the study-area villages to Bamako strong?

Adaptive capacity lies in the current/future abilities & inabilities to implement effective, long-term responses, determined in part by an understanding of previous impacts/responses. Which villages were officially selected to participate in the management transfer program? Have selected villages showed slow significant new wood-cutting? Why or why not? Have non-selected villages showed slow significant new wood-cutting? Why or why not? How are the forests responding to the cutting? What are the prospects for alternative energy technologies? Following the WB policies, were some villages able to improve their transport system connecting the villages to Bamako?

SAHELIAN ECOSYSTEMS MULTI-USES & POLITICAL ECOLOGY

Four papers and two projects were proposed on the basis of the existing data to be completed by some further research. Different themes are developed.

1. Trees Making Territory, Territory Making Property in Mali

The thesis is that new projects create territorial practices but not always in the way intended. The forestry project had intentional territorial and commoditization goals. The boundaries of the forest project differ from everyday resource use practices. Enclosure of resources exists also in non-project areas as a result of the project. The revolution of 1991 and the decentralization policy, power vacuum for several years, increased action space for individual (internal and external) actors, the forest service first losing power and later strengthening their position again.

There are three arenas where the current property-territory relationships can be examined: AMADER, customary institutions and authorities that allocate rights to harvest wood, and the interaction of the two arenas above. New territory-property dynamics emerge that involve different actors, relationships, and practices. Ordinary people create territory and property rights through their practices; e.g. going to a new woodcutters' association; encroaching upon the territory of neighboring villages; participating in patron-client networks. The main point is that property is being created where it previously did not exist.

The research approach would be a historical re-evaluation of relationships among woodcutters, chiefs, other "old" and "new" authorities, funders, and other actors. Empirical questions for digging through existing data or for new research would be:

- Under what conditions have people cut wood?
- How has this changed over time and why?
- What have been the effects on the forest and on access to the forest?

2. The Cutting Edge: Gender Politics of a Wood Fuel Market in Mali

What is the impact of these gender politics on the status of the forest? The thesis is that the forest project has improved women's economic status and thus changed power relations at the household and community levels between men and women.

Specific research questions would be: How have men reacted to women's increasing economic autonomy? How have women responded to men's attempts to limit their status? What is the impact of these gender politics on the status of the forest? What has been the role of women in the associations and has their power changed over time? Have women used communal labor organizations (ton) in new ways in this process?

3. Thinking like a Peasant: Struggles over People and Resources in a Wood Fuel Market Development Project in Mali

What institutions or arenas do communities use to establish their authority over forest resources? The thesis is that communities use the territorial and institutional dimensions of the wood fuel project to expand their control over people and resources in competition with the State.

One can interpret the forest project as a way of the State to expand its control over people and resources. It involves new institutions and spaces of production and marketing. The mapping of forest management tracts creates new territories and heightened awareness of boundaries. These actions reflect local initiatives to use the wood fuel project to expand their own control over resources.

Related ideas and questions are: Are forests being managed in a "sustainable" manner using conventional forestry "best practices" and measures? Are these measures meaningful? The discrepancy between the ideal forestry management plans and the actual forest practice suggests that best practices are not being followed. Perhaps sustainable forest development is not as important as tax revenues. Are these increasing (wood cutting tax, transport tax)? Are these revenues being used to invest in reforestation?

4. Designing Principles: Formalizing Fuelwood in Mali

The thesis is that the creation of fuelwood markets in Mali, which included establishing lists of right-holders linked to designated areas for cutting, was informed by mainstream common property theory. The project was based on the assumption that there is widespread deforestation caused by fuelwood exploitation and that this process was caused by inefficient (or lack of) management including unclear rights. It was assumed that the process could be arrested by establishing clear rights over specific areas for tree cutting. The project, however, led to opposite effects of those stipulated, such as informalization of rights and increased deforestation.

The general argument is that the attempt to formally clarify social and physical boundaries (two of Ostrom's design principles (Ostrom 1990)) has had perverse outcomes. Association members are not the only ones who are given access to land; boundaries (and contractual practices) are unable to exclude customary social processes that govern and allocate rights to the commons.

The idea is to contrast the Ostrom framework with the outcome of this case study while highlighting the emphasis placed on boundary making in the Ostrom approach. The case also illustrates how the issue of power is absent in the Ostrom model and illustrates the risks of blueprint development.

5. Pruning the Malian State: Forestry Reform in the Filières bois-énergie

The thesis is that the Mali forestry project represents an effort of international development interests to domesticate the Malian state and its forestry sector, make it congruent with rational forestry practice,

and future economic development interests. The thesis is that fuelwood development is merely a "stepping stone" to more formal and highly capitalized energy development. The use of neo-institutionalism is essential to this effort. Some questions:

- How is governance understood to function under the idealized regime?
- How is decentralization viewed?
- How is enclosure of common pool resources viewed?

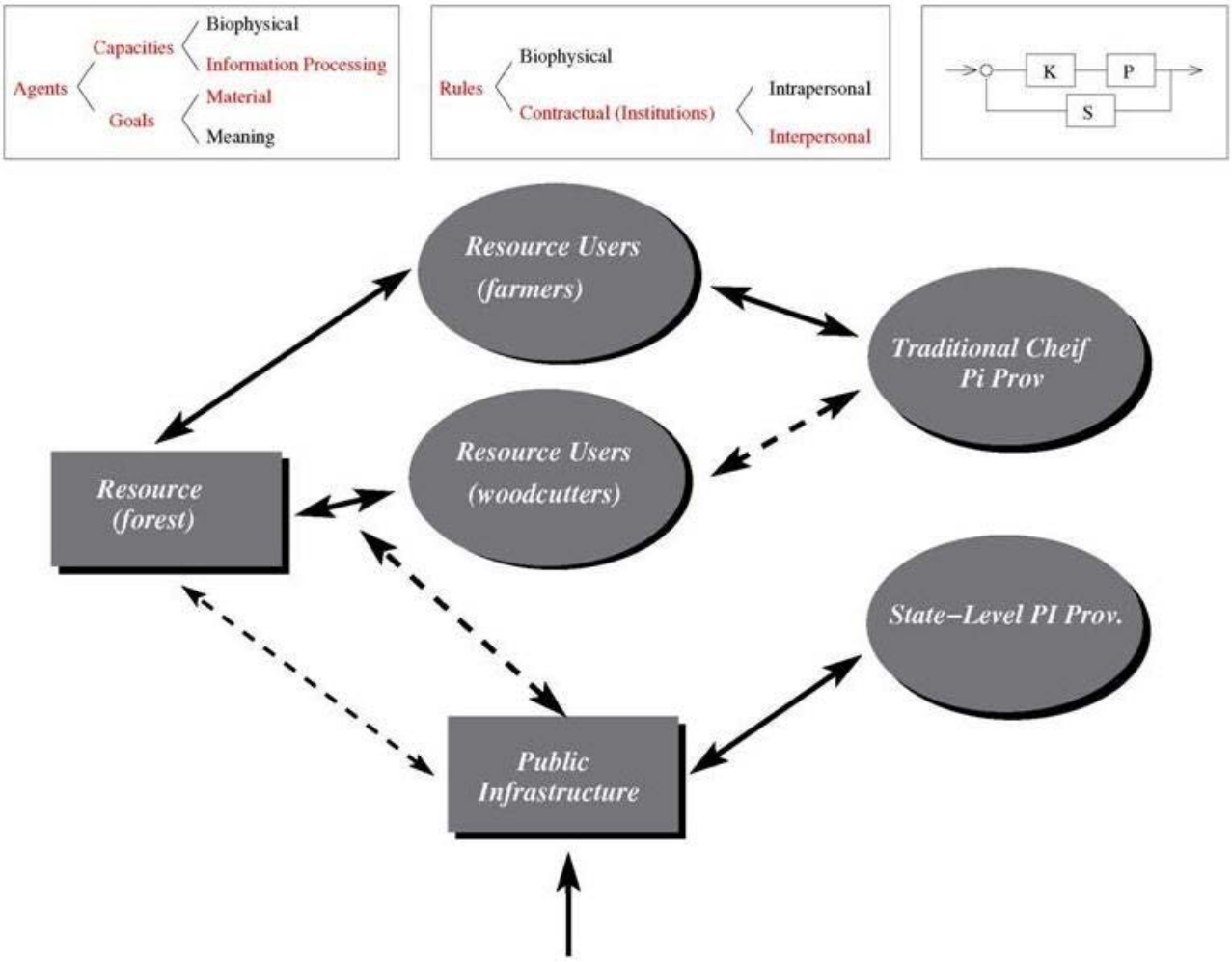
This would be approached through an oral history of state agents, World Bank personnel, and consultancy experts over the life of the project.

6. Learning Space: Instilling Territorial Skills in Villagers, Foresters, and Woodcutters in Mali's Energy Reform Plan

The thesis is that in order to transform Malian natural resource management, the project fosters new identities for state actors and citizens, all associated with a specific territorial and property logic, and tied to specific market skills. [similar to paper 1] The main questions [different from paper 1]: What did the program achieve that it intended to? How did it sociologically transform both the project administrators and the objects of their attention?

Some additional questions: Who – specifically - was employed through the consultancies (international and Malians consultants) - what is their training and what has been their experience? E.g., how is mapping understood by them? How are maps, territories, and commodities described, identified, and associated with groups by people themselves - in their own words (we have few "words" as evidence from the case study material) - and their understandings of the process of change. The approach would be an ethnography of state actors.

SAHELIAN ECOSYSTEMS MULTI-USES & ROBUSTNESS



The main shock is on the public infrastructure. A new policy came. This policy is a good example of a high modernist idea of soft paternalism. There is a lack of awareness between the two public infrastructure providers, ie the traditional chiefs and the state level. There is a problem of information, a lot of uncertainty for sellers and producers. As well middlemen need information on the supply.

SAHELIAN ECOSYSTEMS MULTI-USES & ECOSYSTEM SERVICES

The main entrance was stated by the overarching question: What impact has the constellation of fuelwood policies in the Bamako catchment had on ecosystem service flows?

A set of subsidiary questions where proposed: How have the fuelwood policies affected market structure and trade volumes, relative prices, relative incomes, property rights to land and other natural resources, land use, land cover and biodiversity, in the Bamako Footprint Area (BFA)? What affect does this array of impacts have on the supply of ecosystem services (provisioning, regulating, cultural)?– What are the most important ecosystem services? How have the physical flows of these important ecosystem services changed? What are the spatial reach and variability of each ecosystem service, and how has the spatial reach and variability changed? How has the temporal variability in the delivery of each service changed? How resilient are the flows (are there thresholds in the system)? What have been the consequences of the Bamako fuelwood policies for the value of natural capital (in restricted access

common property, open access common property and 'private' property ? What have been the consequences for other assets? What are the consequences of this for sustainability in the BFA?

To determine the baseline status of Bamako Footprint Area, it is suggested to collect data and determine protocols for sampling sites where the fuelwood policies have had qualitatively different impacts according various criteria. The landscape dimension should be considered and there should also be protocols for scaling up from sample sites to the landscape.

As well, data on biodiversity might take the form of species distribution maps associated with habitat types, or with property status of the land combined with estimates of changes in the size of each habitat or property type. To complete the information concerning the most important ecosystem services and their changes, they suggest to study public investments in different services (food, water, health, etc.) and the historic distribution of natural disasters and cost (disease outbreak, landslides, etc.). This could be done by an anthropological assessment of cultural services and using World Bank Household Surveys (sources of income, expenditures, etc.) and estimation of production functions for each service (or subservice).

Another lack of information identified concerned the spatial reach and variability of each ecosystem service, and changes in its spatial reach. To study this, one should do:

- "Mapping " of each ecosystem service to primary mode of transport (trade, air currents, water currents, biological vectors, species contact, internet connections, etc.)
- Data and models assessing modes of transport, and changes in modes of transport, e.g. "Before and after" mapping of, e.g. disease outbreak, fuelwood, food supply by season, sediment loads in rivers, landslides...

Data informing how resilient are the flows (are there thresholds in the system) should be gathered also, through the assessment of services most likely to experience thresholds. For example one may study the provisioning services due to ecological thresholds (non-linear changes in vegetation communities), the regulating services due, e.g., to changes in disease endemism, draw on modelling and experimental evidence in similar systems to determine what impact the array of social and ecological changes is likely to have on thresholds in the system.

Finally, ane outline of a project to answer the generic research question: if the full array of (spatially and temporally distributed) ecosystem services delivered by specific landscapes, and the full set of (spatially and temporally distributed) beneficiaries of those services are taken into account, how should this affect landscape management over the expected range of conditions?

Such a project would have 6 tasks:

- Develop protocols and methods for identifying the ecosystem services corresponding to the abundance and diversity of different functional groups;
- Identify the pathways for delivery of services/disservices to beneficiaries/victims off-site and the effectiveness of mechanisms for the governance of such flows;
- Analyze the implication of environmental and socioeconomic conditions in source and sink areas for the valuation of off-site ecosystem services,
- Evaluate the trade-offs between ecosystem services delivered at multiple spatial scales;
- Model the consequences of specific perturbations in conditions affecting both the generation of spatially distributed ecosystem services, and their impact in distant locations;

- Support development of mechanisms for internalizing the effects of off-site ecosystem service flows.

And three phases:

1. Phase 1: identification and quantification the ecosystem services flows. Reference sites with significant existing data on ecological functioning and ecosystem processes would be selected, then extending existing research on ecological functioning to identify ecosystem services delivered at a variety of spatial and temporal scales.
2. Phase 2: estimation of the value of non-marketed ecosystem services to off-site beneficiaries (both the source of spatially distributed environmental externalities, and their value to beneficiaries).
3. Phase 3: identification of governance mechanisms – institutions and incentive systems – that have the potential to induce sustainable provisioning of ecosystem services across scales.

SAHELIAN ECOSYSTEMS MULTIPLE USES & MENTAL MODELS

When culture collides: The overarching question is how does perceived power influence dominant narratives?

If each group gets its own contribution, is there any way of knowing the outcome? PE would say that power would define it. Here power is a representation: people think that they have power, other think that they have not.

Same methods that usually: In the document analysis we would be looking at reference networks: how people are cross referenced in the documents. Interviews will give information on the perceived power.

The key groups would be picked with clear document sets, clear narratives: world bank, NGO, academic groups. Representatives of these groups on their perceptions of the other would be interviewed.

The contribution

- For the case study, it would be to know the perception of the other groups, to trace the sources of narratives and see the relationship between the narratives and action.
- For the theory, it would be the merging of mental models as a function of perceived power.
- For action, it would be making sense of intelligent probes. For instance, policy makers implementing a rule, how do they measure the effects?

CAMARGUE

CAMARGUE AND VULNERABILITY

The overarching question is: what explains the vulnerabilities of the reedbed managers in the Camargue, and the other users of these lands associated with the climate change (sea-level rise, flooding), fragmenting water-management system (public vs private)?

The study would be done with the exposure-sensitivity-adaptive capacity frame

Exposure: What is the map of: current sea levels? subsidence rates? flood-height potentials? public/private water management? reedbed lands, divided into multi-use versus single-use? patterns of hunting species migrations

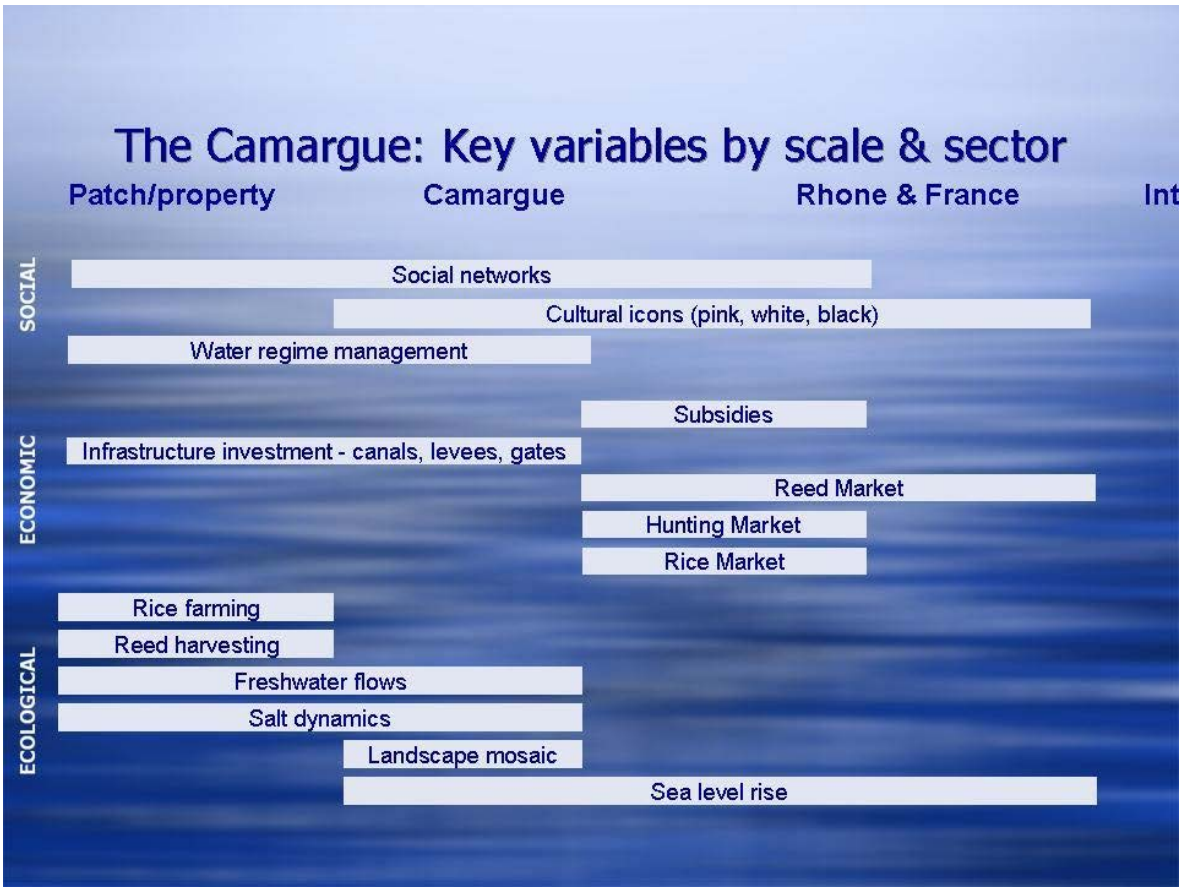
Sensitivity: What is the current status of the water system engineering structures? What is the variation of reedbed productivity with the increase of sea levels in the field? (where sea levels ≈ "high" water levels) What are short-term responses by reedbed managers to such impacts? What are short-term responses by the water management system to such impacts? What is the variation of hunting conditions with the increase of sea levels in the field? What are short-term responses by reedbed managers to such impacts? What are short-term responses by the water management system to such impacts? What is the local "sense of place," and does this local heritage reduce these sensitivities?

Adaptive capacity: The questions are the same but one should consider the long-term responses instead of short term responses.

CAMARGUE AND RESILIENCE

The Camargue socio-ecological system is a large wetland complex at the mouth of Rhone River, and supports a range of land uses including agriculture, biodiversity conservation, and some industry (Mathevet 2004). Cultural icons of pink flamingos, white horses and black bulls are synonymous with the Camarge and reflect a diverse set of social values embedded in this internationally known wetland. At the landscape level, the wetland vegetation composition and type are structured by physical factors of surface elevation, soil salinity and the depth and duration of flooding. The area has saline, brackish and freshwater wetland associations, the type is depending upon proximity to the Mediterranean and the ability of managers to manipulate freshwater input and drainage.

The preliminary results on the scales and dimensions of these key variables are on the following figure



One type of ecological phase shift involves the transition between different types of wetland systems, one dominated by reeds, the other by open water. A landscape of reedbeeds and marshlands supports diverse social goals of conservation, economic harvests of reeds and birds. Reedbeds are dominated by plants of the genus *Phragmites*. These reedbeeds support a diversity of bird species, including herons and passerines. The reeds are harvested for use in construction of traditional roofs throughout Europe. The reedbeds are resilient to a wide range of freshwater hydrologic conditions. Mechanized harvest that damages rhizomes, coupled with sustained flooding can facilitate the transition to open water systems. The open water- marsh system can support duck and coot populations, which are the desired targets of hunters. Such transitions can be managed, as well as other types of potential land use conflicts such as hunting and agriculture.

The big picture of the evolution of the SES starts with the Roman Era where landscape types depend on floods, sediments, sea level, and biological processes. Drainage was made on the 16th century establishing an hydrological network and favoring large estates (reeds, grazing, fishing, hunting). Then came the control period (18-19th century) during which pump stations were used (instead of gravity drainage) and the development of bulls, horses and vineyards. Big floods occurred in 1856. The 19-20th century are the “iconic age”: writers developed the image of disappearing landscape, investment in land was high. The last period is the period of conservation age (20th century) with the development of tourism.

These elements lead to discuss the cultural landscape resilience, and more precisely the relationships between the mix of land (mosaic and patchy landscape) and resilience. Scholars using resilience lens would focus on both (i) its dependence on how local communities and stakeholders managed flips at smaller scales (reed harvest/duck hunting, rice / wheat cropping) and (ii) its dependence on reversibility of regimes. Water levels trigger the flips between states, water regime management at smaller scales reinforces landscape level heterogeneity of land cover and human activities.

CAMARGUE AND COMPLEXITY AND THE COMMONS

Camargue is an interesting case study to explore adaptations and change over time because of the availability of data on actors and institutions; communities and land owners. To further exploration of the system wide change of institutional landscape, it was suggested to answer a set of questions related to the historical analysis: What were the different uses of landscape? What were and are formal and informal rules? When and how did rules change? What were the disturbances and stresses? What were the conflicts (court cases)?

It may be interested also to explore the myth of the Camargue. How did the perception of the role of the Camargue change over time throughout analysis of discussion in media/newspapers/archives. And how did this explain institutional changes?

Different communities were implanted in Camargue (gypsies, spanish, other immigrant groups). How did they evolve over time? What is the role of the social networks? .

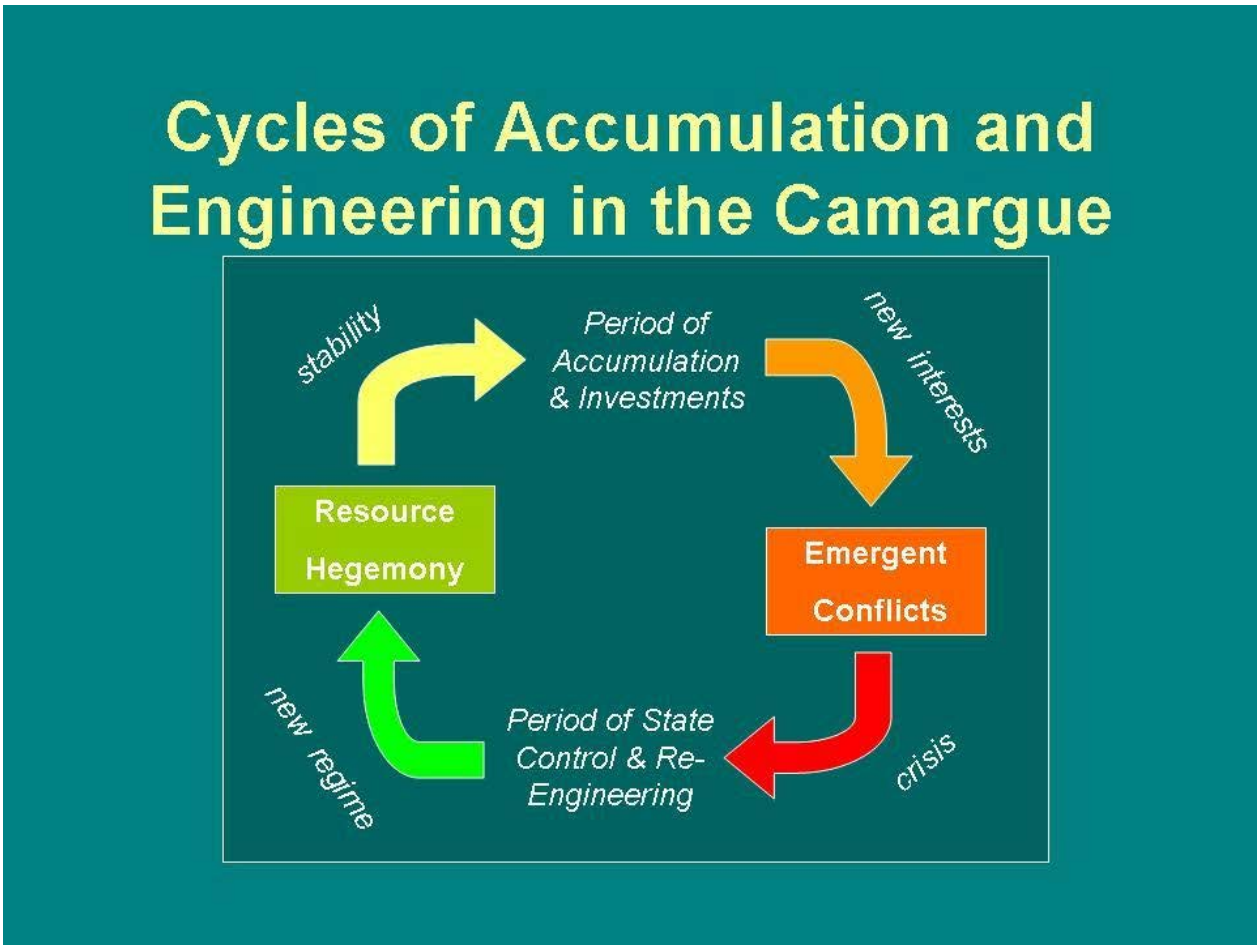
Concerning land owners, it may be useful to develop monographs and studies on: How did land owners adapt over time? When did and how they initiate change? What were intended and unintended changes (change from harvesting the land to harvesting subsidies, changes in land use (rice, wine, tomato)? What is the difference between farmers and conservation groups? The statement of changes, the presence of more diverse types of landowners over time: will this reduce the adaptive capacity?

CAMARGUE AND POLITICAL ECOLOGY

Public water, private land: a political-ecological history of the French Camargue

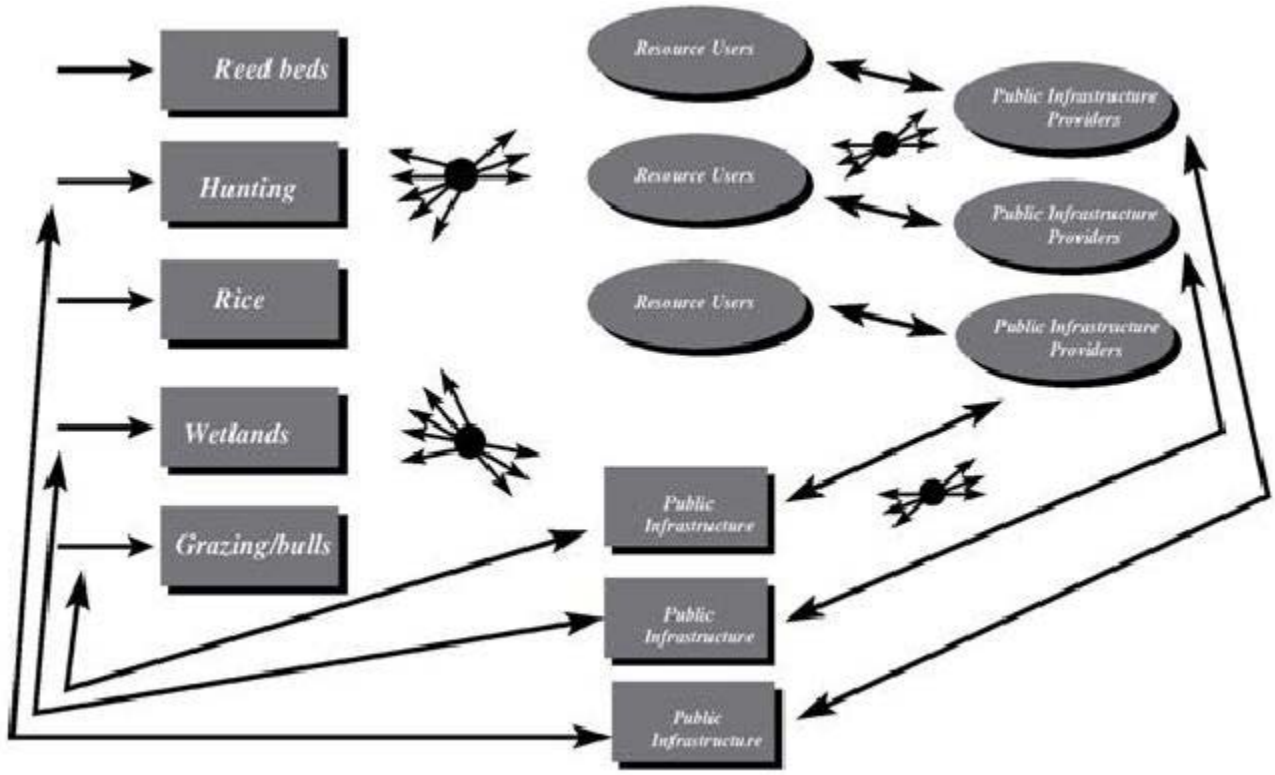
Firstly, contemporary conflicts over land-use and water rights, mainly bird habitats disappearing, less reed bed, are not local and not new and not really about birds. Present conflict is finally one iteration of repeated historical pattern: controlling flows, levels, and salinity of water, to facilitate private uses. Water and land ecologies produced and changed, the water is a “public” resource directed toward private uses and commoditized, and “multiple uses”: accumulation by extra-economic means. Accumulation and power regimes changed over time. The focus on reed beds in Western Camargue showed (i) the creation of new environments/landscapes and property regimes through “crisis” and “calm” scenarios (treaties); (ii) the governance of conflict by expanding the “pie”; (iii) the main constants remain: marshlands consisting of water and land and “wise use” of agro-pastoral landscapes; (iv) the “public” water access to produce private property in land and land-based resources.

The cycles of accumulation and engineering are illustrated in the following figure.



From a theoretical perspective, the case study illustrated the industrial revolution enclosures and especially the regional-national struggles and internal resource colonies. The PE perspective brings a way to analyze the articulations between public resources (water in its various forms) and private uses (for land uses). The flow of values comes from land use; land uses are dependent on the level, flow and characteristics of public water system. To go deeper, histories of water uses and changes were detailed; how current set of water conflicts came to be? The contemporary conflict is a manifestation of a longer set of struggles, precipitated by the long-term, on-going dynamics of accumulation and control of public water to fuel private interests. Engineering public water creates stable economic regimes on private lands, leading to accumulation by key interests. New articulations of the local economy with commodity demands and global conservation dynamics place new and increasing demands on this stable system, however, eventually leading to crisis. Each crisis leads to a new apportionment of water, deferring solution of the core conflict source (private land-based accumulation) by focusing on allocation of a dwindling water regime.

CAMARGUE & ROBUSTNESS



In Camargue case stakes are very high; there are many public infrastructure and lots of public infrastructure providers. Resource users are very linked to public infrastructure providers. There is a problem of spiraling complexity between public infrastructure providers and public infrastructure. It is functioning well because there are many feedbacks, because it is valuable. In the history, as the pressure on the system is high the public infrastructure changes (changing the water flow mainly). So at each stage a new set of relations between R, PI and PIP is built. Camargue is so productive that it has capacity to relieve scarcity. However the spiraling complexity leads to hidden fragility.

CAMARGUE & ECOSYSTEM SERVICES[5]

Biodiversity and its services can (arguably) be considered the heritage of all humankind, and not just of the people living near it. What are the "off-site" ecosystem services (dis-services)? Some are discussed for region (e.g., mosquitoes in Montpellier) but what are some others? Global flows? Carbon sequestration? Pharmaceuticals? Disease?

Is it possible to do an assessment of inclusive wealth? Not just the value of biodiversity and ecosystem-service flows, but also the built and financial capital the human and social capital, for different land use and land cover regimes?

[5] Reminder : C.Perrings and A. Kinzig had a very short time studying this case study

CAMARGUE & MENTAL MODELS

In Camargue there would be a focus on social representation as relationships between identity, place and practice. How identity, place and practice influence each other?

Methods and data. There would be investigation on groups of stakeholders, at different time (the different stakeholders ages), and situations (Where are you getting the information? is it in the field? At home?).

Same method than other studies would be used. Media analysis, interviews to derive themes and interviews to look at consensus. The idea of consensus seeking instead of variety of representations comes from the fact that we are here looking to identity, a sense of place. Is there such a consensus?

The contribution:

- To the case study, are there emerging identities, what would be the merging identities (ex: a tourism operator)? What are the implications for place and practice?
- To the theory: what is the relationship between the settings and the mental models?
- To action: can you stimulate the construction of new identities as a mechanism for solving problems, conflicts, to construct new identities, places and practices that would be desirable? How to build stewardship?

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